PB-235 386

LAND APPLICATION OF SEWAGE EFFLUENTS AND SLUDGES

SELECTED ABSTRACTS

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY

PREPARED FOR
OFFICE OF WATER RESOURCES RESEARCH

JUNE 1974

DISTRIBUTED BY:
NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. 2.

PB 235 386

W74-11577

4.
LAND APPLICATION OF SEWAGE EFFLUENTS AND SLUDGES: SELECTED ABSTRACTS,

5. Report Date

6.

8. Performing Organization Report No.

9.
Water Quality Control Branch
Robert S. Kerr Environmental Research Laboratory
~~U.S.~~ Environmental Protection Agency, Ada, Oklahoma

11. Type of Report and Period Covered

12. Sponsoring Organization

15.
Environmental Protection Agency, Technology Series
Report ~~No~~. EPA-660/2-74-042, ~~249 p.,~~ June 1974. 248p,

Current concern about environmental conditions has focused renewed attention on land application as a waste management technique. This report combines selected abstracts from previous publications and updates the sources abstracted into the year 1973. The 568 abstracts selected for inclusion are arrayed in chronological groupings and are identified as to emphasis on effluent or sludge. An author index and a subject matter (descriptor term) index facilitate reference to specific abstracts or to abstracts addressing narrower subject matter areas. Countries, states, and, in some cases, actual project locations are included in the subject matter index as geographic locators. (Thomas-EPA)

17a. Descriptors
*Municipal wastes, *Wastewater treatment, *Sludge disposal, Irrigation systems, Land reclamation, Groundwater recharge, Public health, Crop response, Cost comparisons, Soil properties, *Abstracts, *Water reuse, Sprinkler irrigation, Economic feasibility, Waste water disposal

17b. Identifiers
*Infiltration systems, *Overland flow systems, Pre-treatment (wastewater).

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17c. COWRR Field & Group 05D, 05E, ~~06E~~, 03C, ~~04A~~ 10C

Copy Available from GPO Sup Doc as EP1.23:660/2-74-042, $2.20; microfiche from NTIS as PB $1.45	19. Security Class. (Report) 20. Security Class. (Page)	21. No. of Pages 275 22. Price 5.30-1.45	**Send To:** WATER RESOURCES SCIENTIFIC INFORMATION CENTER U.S. DEPARTMENT OF THE INTERIOR WASHINGTON, D. C. 20240
Richard E. Thomas		Environmental Protection Agency	

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Monitoring, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

EPA-660/2-74-042
June 1974

LAND APPLICATION OF SEWAGE EFFLUENTS AND SLUDGES: SELECTED ABSTRACTS

by

Water Quality Control Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma

Program Element 1BB045

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.80

ABSTRACT

The literature on applying sewage effluents and sludges to the land has been annotated quite thoroughly through the year 1965 in previous publications. The purpose of this report is to combine selected abstracts from these previous publications and to update the sources covered into the year 1973. The period from 1968 into 1973 represents a very active period during which the literature reflects the current attractiveness of land application approaches as an advanced waste treatment approach.

This report includes 568 selected abstracts which have been compiled as part of several EPA contracts on land application of sewage effluents and sludges. These abstracts have been arrayed in chronological groupings and identified as to emphasis on effluent or sludge. The report also includes an author index and a subject matter (descriptor term) index to facilitate reference to specific abstracts or to abstracts addressing narrower subject matter areas. Countries, states, and, in some cases, actual project locations are included in the subject matter index as geographic locators.

TABLE OF CONTENTS

	Page
Abstract	ii
Preface	iv
Acknowledgments	v
User Guide	vi
Author Index	vii
Descriptor Term Index	xiv

Section

I	ABSTRACTS PRIOR TO 1941	1
II	ABSTRACTS 1941 THRU 1950	18
III	ABSTRACTS 1951 THRU 1955	35
IV	ABSTRACTS 1956 THRU 1960	71
V	ABSTRACTS 1961 THRU 1965	105
VI	ABSTRACTS 1966 THRU 1970	142
VII	ABSTRACTS 1971 AND LATER	201

PREFACE

Application of wastewater to the land as an alternative or as an adjunct to more conventional methods of wastewater management is receiving increased attention as a result of recent environmental concerns and legislation. Byplay generated through the brash claims of strong proponents and the counter statements of adament opponents regarding the viability of land application approaches confuses one seeking reliable information to support objective decisions for selection of a wastewater management alternative. EPA has recently supported several contract studies to put land application processes into proper perspective with the more conventional concepts of partially removing specified impurities and then discharging effluents directly into watercourses. The results of these contract studies reiterated the fact that land application of sewage predates all of the more conventional approaches to treatment and direct discharge to watercourses. It is of interest to note that some of the land application systems in operation at the present time were constructed and placed in operation prior to the development of such waste treatment concepts as the rotary sprinkler for trickling filters, the Imhoff tank, or the activated sludge process.

Over one thousand articles were perused during the conduct of three EPA contract studies which were initiated to (1) survey existing facilities using land application of wastewater, (2) assess the state-of-the-art for applying municipal effluents to the land, and (3) assess the state-of-the-art for applying municipal sludges to the land in the eastern United States. The 568 abstracts included in this report were compiled from the literature citations which the contractors for these three studies deemed most relevant to a thorough understanding of the current state-of-the-art. The recent surge of attention directed to land application of wastewater is highlighted by noting that 237 of the 568 abstracts included are for reports prepared since the publication of our previous annotated bibliography covering the period through 1965.

ACKNOWLEDGMENTS

Compilation of abstracts for this report has been achieved through the cooperative efforts of the Office of Research and Development and the Office of Water Programs Operations of EPA and several of their respective contractors. The diligent efforts of all of the individuals involved are gratefully acknowledged.

The following contributors conducted literature searches and furnished abstracts which have been included in this report:

> American Public Works Association Research Foundation, Richard H. Sullivan, Project Director, and Belford L. Seabrook, EPA Project Officer.
>
> Metcalf and Eddy, Inc., Charles E. Pound, Project Director, and Richard E. Thomas, EPA Project Officer.
>
> Battelle Columbus Laboratories, Joseph M. Genco, Project Director, and G. Kenneth Dotson, EPA Project Officer.
>
> East Central Oklahoma State University at Ada, Oklahoma, Dr. Ralph H. Ramsey, Project Director, and Richard E. Thomas, EPA Project Officer.
>
> Water Quality Control Branch, Robert S. Kerr Environmental Research Laboratory, EPA, Dr. James P. Law, Jr., Project Director.

Compilation and indexing of the report was conducted under the supervision and direction of Richard E. Thomas, with the unwavering and gratefully appreciated assistance of Joan Elliott, J. Lorene Fuller, and Ann Runyan. This task could not have been accomplished without the excellent guidance provided by Dr. Curtis C. Harlin, Jr., Chief of the Water Quality Control Branch.

USER GUIDE

The 568 abstracts included in this report have been arrayed and indexed in a manner intended to facilitate use by interested persons with diversified interests. The basic array of a chronological grouping is supplemented with wastewater source identifiers, a subject matter index including geographic descriptors, and an author index. The chronological array was chosen to serve the reader with a desire to make a historical synopsis or to peruse information generated over a specific but limited time span. Since the compilation of abstracts covers articles addressing municipal effluents, sludges, and industrial wastewaters, the accession number for each entry contains an alphabetic descriptor which identifies the primary waste source covered in the subject abstract. The alphabetic descriptors are: "M" for municipal effluents, "S" for sludges, and "I" for industrial wastewaters. These alphabetic descriptors provide the means for a user to select abstracts addressing a specific category of waste source when using the subject matter index of descriptor terms. The subject matter index is composed of some 185 descriptors selected from the current issue of the Water Resources Thesaurus. In addition to these subject matter descriptors, the names of countries, states within the United States, and, in some cases, project locations are included in the subject matter index as geographic locators. The author index includes the senior author and the first two coauthors for those articles listing more than three authors.

This compilation of abstracts has been drawn from multiple sources with differing techniques for citing sources, choosing descriptor terms, and preparing abstracts. An earnest and concerted effort has been made to achieve the integration of these abstracts into a single report which maintains clarity of meaning and provides an accurate literature citation for referral to the original articles. Users who find errors in literature citations would be doing their fellow users a service by calling such errors to our attention for correction in subsequent revisions of this compilation of abstracts.

AUTHOR INDEX

Abbot, A. L., 042 M
Adel'son, L. I., 246 M
Agricultural Research Service, 467 S
Allen, M. L., 468 M
Allender, G. C. 469 M
Allison, C., 043 I, 070 I
Allison, L. E., 044 M
Amirov, R. O., 341 M
Amramy, A., 247 M, 340 M
Anderson, A., 470 S
Anderson, D. R., 342 I
Anderson, M. S., 084 S, 159 S
Anonymous, 001 S, 002 M, 003 M, 045 M, 046 M, 082 M, 083 M, 085 S, 160 I, 161 M, 162 S, 163 S, 242 S, 243 S, 244 S, 245 I, 332 I, 333 M, 334 S, 335 M, 336 S, 337 S, 338 I, 339 M, 464 M, 465 S, 466 S
Askey, J. B., 248 M
Aulenbach, D. B., 343 M

Baars, J. K., 164 M, 249 M
Babov, D. M., 250 M
Bachmann, G., 086 M
Backmeyer, D. P., 251 S
Baffa, J., 345 M
Baffa, J. J., 344 M
Baier, D. C., 458 M
Baily, G. W., 346 M
Baker, M. M., 004 M
Banister, 471 M
Banse, H. J., 231 M
Barnette, R. M., 036 M
Bartilucci, N., 345 M
Barton, J. R., 472 M
Bauer, J. H., 252 M
Bauer, W. J., 473 M
Beckett, F. E., 347 M, 357 M
Behnke, J. J., 350 M
Bell, J. W., 087 I
Bendixen, T. W., 283 M, 348 M, 349 I, 437 M, 447 M, 449 M
Berg, E. J. M., 144 M, 173 M
Berger, B. B., 165 M
Bieri, F. K., 093 I
Billings, R. M., 166 I
Black, R. J., 253 S
Blaney, H. F., 254 M
Bloodgood, D. E., 196 I
Blosser, R. O., 183 I, 255 I
Blumel, F., 256 M
Bocko, J., 167 M, 257 M, 258 M, 351 M
Boen, D. F., 474 M
Bollag, J. M., 475 M
Bolton, P., 047 I
Bonderson, P. R., 259 M
Borne, B. J., 238 M
Bott, R. F., 248 M, 412 M
Bouwer, H., 352 M, 353 M, 354 M, 476 M, 477 M
Bowerman, F. R., 223 M
Boyce, E., 064 M
Braids, O. C., 495 S, 512 S
Breska, G., 168 I
Brown, H. D., 088 I
Bruvold, W. H., 478 M
Bunch, R. L., 260 M
Bunts, J. H., 474 M
Bur.Sanit. Eng., 355 M
Bush, A. F., 089 I
Butler, R. G., 090 M, 124 M, 219 M
Buxton, J. L., 356 M

Calise, V. J., 111 M
Canham, R. A., 091 I, 169 I, 170 I
Cannon, D. W., 261 I
Cantrell, R., 280 M
Cantrell, R. P., 357 M
Carlson, D., 387 I
Cecil, L. K., 263 M
Champlin, H. H., 529 S
Chapman, C. J., 262 M
Chase, W.J., 171 M
Cleary, E. J., 034 S
Coast Laboratories, 048 I
Coerver, J. F., 358 M
Cohen, J. M., 306 M

Coker, E. G., 264 S
Cole, H., 359 M
Conn, R. L., 360 S
Connell, C. H., 172 M, 173 M, 265 M
Conrad, E. T., 445 I
Convery, J. J., 444 M
Corker, C. E., 479 M
Cormack, R. M. M., 266 M
Cornell, 480 M
Crawford, A. B., 005 M
Crawford, S. C., 174 I
Cripps, T., 416 M
Crites, R. W., 525 M, 526 M
Crosby, J. W., 361 M, 479 M
Culp, R., 362 M
Currie, R. J., 474 M

Dalton, F. E., 363 S
Damoose, N., 049 S
Danford, J., 529 S
Davis, G. E., 364 M
Davis, G. W., 481 M
Dawson, R. N., 482 M
Day, A. D., 175 M, 176 M, 267 M, 483 M
Dean, B. H., 186 M
Dean, R. B., 365 S
Deaner, D. G., 366 M, 484 M
Dee, N., 485 M
Delano, E. H., 177 S
Dennis, J. M., 092 I
Dept. of Dairy Technology, 486 I
Derby, R. L., 178 I
DeTurk, E. E., 006 S
DeVries, J., 487 M
Dickerson, J. A., 443 S
Diehl, P. A., 007 M
Dietz, M. R., 179 I
Dinges, W. R., 367 M
Dodolina, V. T., 488 M
Drake, C. H., 361 M
Drake, J. A., 093 I
Drewry, W. A., 368 M
Driver, C. H., 369 M
Drynan, W. R., 185 M
Dubyne, F. T., 349 I
Dundas, W. A., 050 S
Dunham, A., 481 M
Dunlop, S. G., 094 M, 095 M, 096 M, 152 M, 268 M, 370 M
Dunstan, G., 097 I
Dye, E. O., 180 M, 269 M, 371 M
Dziezyc, J., 270 M

Eastman, P. W., 372 M
Ebbert, S. A., 181 I
Eberhardt, H., 271 S
Ebly, J., 489 M
Eckenfelder, W. W., 373 I
Eddy, H., 008 M
Eddy, H. P., 021 M
Ehlers, V. M., 009 M
Eichen, M., 499 M
Eier, D. D., 459 M
Ekern, P. C., 567 M
Eldridge, E. F., 051 I
Eliassen, R., 272 M, 368 M, 374 M
Elliott, 471 M
Ellis, B. G., 490 M
Engelbert, L. E., 105 I
Ermer, H., 271 S
Escarcega, E. D., 477 M
Ettinger, M. B., 260 M
Etzel, J. E., 562 M
Evans, J. O., 375 S

Fair, G., 017 M
Falk, L. L., 052 M, 130 M, 131 M, 132 M, 133 M, 134 M, 135 M
Falkenhain, H. S., 098 S
Feinmesser, A., 281 M, 376 M, 390 M
Fish, H. H., 377 M
Fisk, W. W., 273 I
Fleming, J. R., 182 S
Fleming, R. R., 274 M
Flower, W. A., 275 I
Forbes, M. C., 265 M
Forstner, M. J., 378 S
Foster, H. B., 276 M, 379 M
Frank, A. H., 005 M
Frankel, R. J., 380 M
Frodey, R. C., 179 I
Fuhriman, D. K., 472 M

Gaffney, M. P., 491 S
Gallatin, M. H., 236 M
Gellman, I., 183 I

Gilde, L., 382 I
Gilde, L. C., 381 I, 492 I
Gillespie, C. G., 010 M
Glantz, P., 383 M
Glathe, H., 277 S
Glavin, T. P., 343 M
Gloyna, E. F., 185 M
Goldshmid, J., 493 M
Goldstein, J., 384 S
Goncharuk, E. I., 386 M
Goodwin, E. H., 011 M
Gorodetskii, T. G., 279 M
Gotaas, H. B., 101 M, 198 M
Gray, H. F., 053 M, 061 M
Gray, J. F., 278 M, 385 M
Greenberg, A. E., 099 M, 100 I, 186 M
Grewal, N. S., 506 M
Grigor'Eva, L. V., 279 M, 386 M
Grubinger, H., 102 S
Guerri, E. A., 494 I
Guter, K. J., 541 M
Guttormsen, K., 387 I
Guymon, B. E., 184 M

Haas, F. C., 388 I
Hajek, B. F., 389 M
Halamek, F., 054 M
Hale, H. H., 088 I
Handloser, M., 224 M
Harding, H. G., 103 I
Harlin, C. C., 550 M
Harmon, J. A., 218 M
Harmsen, H., 187 M
Harper, H. J., 012 S
Harrell, R. B., 013 M
Harvey, C., 280 M
Haskell, E. E., 350 M
Hayes, 480 M
Hayob, H., 104 S
Hedger, H. E., 055 M
Henry, C. D., 105 I
Hermann, E. R., 185 M
Hershkovitz, S. Z., 281 M, 376 M,
 390 M
Herzik, G. R., 188 M
Heukelekian, H., 189 M, 190 M
Hickerson, R. C., 191 I
Highsmith, R. M., 282 M
Hill, R. D., 283 M, 348 M, 349 I
Hinesly, T. D., 391 S, 495 S, 512 S
Hirsch, [illegible]., 284 I, 392 M
Hodgkinson, C., 199 M
Holler, K., 106 S
Hopkins, G., 192 I
Hopkins, G. J., 126 I
Hopkins, R. M., 542 M
Horner, R. W., 496 S
Howland, 480 M
Hunt, C. F., 443 S
Hunt, H. J., 107 M
Husemann, C., 285 S, 286 M
Hutchins, W. A., 014 M
Hyde, C., 016 M
Hyde, C. G., 015 M, 056 M

Imhoff, K., 017 M
Ippolito, G., 108 M
Isaac, P. C. G., 287 M

Jacks, T., 383 M
Jackson, F. A., 193 I
Jackson, L. W., 057 S
Jenkins, D., 289 M
Jepson, C., 109 M
Johnson, C. E., 194 M
Johnson, W. E., 195 M
Johnstone, D. L., 361 M
Jones, J. H., 288 M
Jopling, W. F., 379 M, 412 M
Julen, G., 110 M

Kabler, W., 123 M
Kardos, L. T., 393 M, 394 M, 497 M,
 498 M, 537 M, 538 M, 539 M
Karnovsky, F., 395 S, 396 S
Kasperson, R. E., 499 M
Katko, A., 299 M
Keating, R. J., 111 M
King, P. H., 408 I
Kirby, C. F., 500 M
Klein, A. S., 289 M
Koch, H. C., 196 I
Kolb, J., 501 S
Korbitz, W., 502 S
Kowalski, J., 197 M
Koziorowski, B., 112 M
Krese, R. B., 409 M
Kreuz, C., 290 I

Kreuz, C. A., 018 M
Krone, R. B., 198 M, 199 M, 397 M, 410 M
Kruez, C. A., 113 S
Kudryavtseva, B. M., 398 M
Kuo, T., 291 M
Kutepov, L. E., 399 M
Kutera, J., 292 M

Laak, R., 400 M
Lance, J. C., 503 M, 504 M
Lane, L. C., 114 I
Larson, W. C., 200 M
Lau, L. S., 567 M
Laverty, F. B., 293 M
Law, J., 404 I
Law, J. P., 401 S, 402 M, 403 I, 448 M
Lawton, G. W., 201 I, 202 I
Leach, R. E., 248 M
Leaver, R. E., 203 S
Leeper, G. W., 505 M
Lehman, G. S., 405 M, 460 M
Lehmann, A. F., 294 M
Leukel, W. A., 036 M
Lewin, V. H., 406 S
Lowe, R. P., 115 M
Ludwig, R. G., 058 M
Lueck, B. F., 157 I
Luley, H. G., 295 I
Lunsford, J., 097 I
Lunsford, J. V., 204 I
Luthin, J. N., 205 M

Makawi, A. A. M., 277 S
Malo, B. A., 407 I
Maloch, M., 059 M
Maloy, T. P., 019 S
Mannering, J. V., 329 M
Marks, R. H., 296 M
Martin, B., 116 M
Mather, J. R., 117 I
Mathur, R. P., 506 M
Mays, D. A., 547 S
McCarty, P. L., 408 I
McDowall, F. H., 206 I
McGauhey, P. H., 090 M, 099 M, 198 M, 207 M, 289 M, 297 M, 409 M, 410 M
McKee, F., 118 I, 208 M
McKee, J. E., 411 M
McKeown, J. J., 298 I
McLaughlin, C. P., 050 S
McMahon, E. K., 191 I
McMichael, F. C., 411 M
McQueen, F., 020 M
Mehrotra, C. L., 314 M
Meighen, A. D., 209 I
Melbourne and Metropolitan Board of Works, 507 M
Melnick, J. L., 509 M
Merrell, C., 229 M
Merrell, J. C., 299 M, 412 M
Merz, R. C., 119 M, 210 S, 211 M, 212 M, 213 M, 214 S, 215 M
Metcalf & Eddy, 508 M
Metcalf, L., 008 M, 021 M
Metcalf, T. G., 509 M
Middleton, F. M., 300 M
Miller, D. W., 510 M
Miller, P. E., 120 I
Miller, R. H., 511 S
Mitchell, G. A., 022 M, 023 M, 024 S, 025 M
Moldenhauer, R. E., 105 I
Molina, J. A. E., 512 S
Molina, J. E., 495 S
Morgan, M., 149 S
Morlock, J., 513 I
Morton, J., 413 S
Moyer, H., 362 M
Mueller, W., 121 M
Mulford, S. F., 089 I
Muller, G., 217 S
Muller, J. F., 026 S
Muller, W., 060 M, 216 M
Murphy, K. L., 482 M
Myers, E. A., 414 M, 514 M
Myers, L., 404 I
Myers, L. H., 403 I

Napolitano, P. J., 415 M
Nat'l. Ass. of State Univ. and Land-Grant Colleges, 515 S
Nat'l. Canners Ass., 516 I
Nat'l. Water Comm., 517 M
Neel, J., 192 I
Nelson, F., 192 I
Nelson, L. E., 122 I
Nesbitt, J. B., 518 M

Niles, A. H., 063 S
Nilsson, K. O., 470 S
Norman, N., 123 M
Nupen, E. M., 519 M

O'Connell, W., 053 M
O'Connell, W. J., 061 M
Oakley, H. R., 416 M
Okun, D. A., 520 M
Olds, J., 417 S
Omel'Yanets, T. G., 279 M
Ongerth, H. J., 218 M
Orenstein, A. J., 062 M
Org. Economic Cooperation and Development, 418 I
Orlob, G. T., 090 M, 124 M, 199 M, 219 M
Overman, A. R., 521 M, 522 M
Owens, E. L., 255 I

Page, H. G., 419 M
Pannier, D., 285 S
Parizek, R. R., 420 M
Parker, R. P., 421 I
Parker, R. R., 301 I
Parkhurst, J. D., 302 M, 303 M, 422 M
Parness, W. H., 423 M
Parsons, W., 424 I
Paulsmeier, F., 125 M
Pearse, L., 063 S
Penn. Dept. of Environmental Resources, 523 M
Pennypacker, S., 425 M
Peterson, H. B., 426 M
Peurifoy, R. L., 027 M
Phelps, E. B., 040 M
Phillip, A. H., 524 I
Pintler, H. E., 299 M
Poon, C. P. C., 427 M
Popp, L., 428 M
Porges, R., 126 I, 220 M
Pound, C. E., 525 M, 526 M
Pouquet, F., 028 M
Powell, S. T., 221 I
Prat, S., 304 M
Pratt, P. F., 284 I
Prochal, P., 222 M
Prucha, A. A., 276 M

Rafter, G. W., 029 M
Ragotzkie, R. A., 130 M, 131 M, 132 M, 133 M, 134 M, 135 M
Rawn, A. M., 030 M, 064 M, 065 M, 223 M
Reed, S. C., 527 M
Reinhold, F., 066 M
Reinke, E. A., 009 M, 031 I, 127 M
Reploh, H., 128 M, 224 M
Reutlinger, S., 305 M
Rice, R. C., 477 M
Richards, S. J., 284 I
Riney, W. A., 032 M
Robeck, G. G., 283 M, 306 M, 307 M, 429 M
Roberts, F. C., 009 M
Rockwell, F. L., 129 M
Rohde, G., 308 M
Rojas, J. A. R., 343 M
Romanenko, N. A., 430 M
Rose, J. L., 431 M
Rose, W. W., 528 I
Routson, R. C., 432 M, 433 M
Rowe, D. R., 415 M
Rudolfs, W., 033 S, 034 S, 130 M, 131 M, 132 M, 133 M, 134 M, 135 M

Sabey, B. R., 529 S
Salimov, D. A., 341 M
Sanborn, N. H., 136 I, 137 I
Sayers, W. T., 306 M
Scanlon, A. J., 225 S
Schaffer, G., 434 S
Schaub, S. A., 541 M
Schliff, L. I., 435 M
Schraufnagel, F. H., 309 I
Schriner, P. J., 067 S
Schulze, K. L., 436 M
Schwartz, W. A., 348 M, 437 M, 449 M
Schwarz, K., 138 M, 139 M
Scott, R. H., 310 I
Scott, T. M., 226 M
Seabrook, B. L., 530 S
Seagraves, J. A., 305 M
Sebastian, F. P., 531 I

Secretary, Hydraulic Resources, Hydrological Comm., Mexico, 438 M
Segel, A., 068 M
Sepp, E., 311 M, 439 M, 532 M, 533 M
Sheaffer, J., 473 M
Sheets, W. D., 088 I
Short, 471 M
Shreier, F., 069 M
Shuval, H. D., 440 M
Shuval, H. I., 312 M
Siebert, C. L., 070 I
Simmers, R. M., 228 I
Sine, R. L., 313 S
Sisson, D. R., 141 M
Skinner, J. F., 035 S
Skogerboe, G. V., 534 M
Skulte, B. P., 227 M
Skulte, P., 140 M
Sladecek, V., 304 M
Smith, R. L., 142 M
Smith, T. P., 522 M
Snyder, W., 143 M
Sopper, W., 535 M
Sopper, W. E., 441 M, 442 M, 443 S, 498 M, 536 M, 537 M, 538 M, 539 M
Sorber, C. A., 540 S, 541 M
Sosewitz, B., 391 S
Spencer, B. R., 071 M
Sprivastava, P. B. L., 314 M
Sprowl, T. M., 542 M
Stafford, J. F., 364 M
Stanbridge, H. H., 315 M
Stander, G. J., 519 M
Stanley, W. E., 064 M
Steel, W., 144 M
Steffen, A. J., 316 M
Stenburg, R. L., 444 M
Stevens, R. M., 544 M
Stickelberger, D., 543 S
Stokes, W. E., 036 M
Stone, A. R., 230 S
Stone, R., 145 I, 146 M, 229 M, 317 M, 445 I
Stowell, E. R., 147 M
Subby, W., 142 M
Subert, C., 043 I
Sullivan, D., 446 M
Sullivan, R. H., 545 M
Summerfield, F., 413 S
Swanick, K. H., 546 S
Swanson, C. L., 444 M
Szerszen, L., 257 M

Tanner, F. W., 037 S
Tatlock, M. W., 038 S
Taylor, G. S., 288 M
Terman, G. L., 547 S
Thackwell, H. L., 148 M
Thomas, J. F., 100 I
Thomas, R., 404 I
Thomas, R. E., 403 I, 447 M, 448 M, 449 M, 548 M, 549 M, 550 M
Thomson, F., 149 S
Thornwaite, C. W., 450 I
Tietjen, C., 231 M
Tilstra, J., 551 M
Todd, D. K., 232 M, 318 M
Tonkin, C. D., 272 M
Travaini, D., 072 M
Travis, P. W., 233 M
Trebler, H. A., 103 I
Triebel, W., 451 S
Trybala, M., 270 M, 319 M
Tucker, T. C., 175 M, 176 M
Twedt, R. M., 094 M, 095 M

U.S. Army Corps Eng., 554 M, 555 M, 556 M, 557 M, 558 M, 559 M
U.S. Dept. Agr., 553 S
Universities, Nat'l. Ass., 515 S
Urie, D. H., 552 M
USDI, Washington, D.C., FWPCA, 452 I

Vaisman, Y. I., 320 M
Van Eyck, M., 560 M
Van Kleeck, W., 150 S, 235 S
Vander Goot, H. A., 234 M
Veatch, M. T., 073 I
Veatch, N. T., 039 M
Vermes, L., 453 I, 563 I
Viessman, W., 321 M
Viitasalo, I., 454 S
Vlamis, J., 322 S, 561 S
Voights, D., 151 I

Wadleigh, C. H., 236 M, 455 M
Wallace, A. T., 459 M
Wallis, C., 509 M
Wang, W. L., 094 M, 095 M, 152 M, 268 M
Ward, P. C., 276 M, 478 M
Warrington, S. L., 153 M
Watson, J. L. A., 323 M
Watson, K. S., 324 M
Wayman, C. H., 419 M
Weber, W. J., 456 M
Webster, R. A., 154 I
Welland, K., 155 M
Weiss, R. H., 325 S
Wells, D. M., 457 M
Wells, W. N., 326 M
Wentink, G. R., 562 M
Werly, E. F., 237 I
Wesche, J., 286 M
Wesner, G. M., 458 M
Westenhouse, R., 327 I
Wheatland, A. B., 238 M
Whetstone, G. A., 328 M
Whisler, F. D., 504 M
Wierzbicki, J., 074 M, 075 M, 076 M, 077 M, 078 M, 079 M, 156 M, 239 M, 240 M
Wilcox, L. V., 080 I, 236 M
Wildung, R. E., 432 M, 433 M
Wiley, A. J., 157 I
Wiley, J. S., 461 S
Williams and Works, 564 M
Williams, D. E., 322 S, 561 S
Williams, R. E., 459 M
Williams, T. C., 414 M, 564 M, 565 M
Wilson, C. W., 347 M, 357 M
Wilson, L. G., 460 M
Winneberger, J. H., 297 M, 409 M
Winslow, C. E. A., 040 M
Wischmeier, W. H., 329 M
Wisniewski, T., 330 I
Wisniewski, T. F., 157 I
Woodley, R. A., 462 I
Wright, C. T., 041 M, 081 M
Wyckoff, B. M., 272 M
Wyndham, R., 566 I

Yackey, H. H., 331 M
Yehuda, P., 241 M
Young, R. H. F., 567 M
Younger, V. B., 568 M

Zimmerman, J. D., 463 M
Zunker, F., 158 M

DESCRIPTOR TERM INDEX

Abilene: 032 M

Activated sludge effluents: 028 M, 189 M, 198 M, 220 M, 221 I, 293 M, 302 M, 345 M, 371 M, 411 M, 422 M, 474 M, 482 M, 530 S

Aerated lagoon effluents: 148 M, 160 I, 400 M, 414 M, 489 M, 493 M, 519 M

Aerobic conditions: 124 M, 288 M, 297 M, 306 M, 315 M, 397 M, 405 M, 449 M

Aerobic digestion: 033 S, 434 S, 461 S, 495 S, 546 S

Aerosols: 212 M, 224 M, 415 M, 427 M, 455 M, 540 S, 541 M

Alabama: 389 M, 547 S

Anaerobic conditions: 043 I, 142 M, 258 M, 422 M, 449 M, 475 M, 512 S, 548 M

Anaerobic digestion: 006 S, 012 S, 019 S, 033 S, 038 S, 048 I, 084 S, 104 S, 159 S, 163 S, 228 I, 235 S, 360 S, 378 S, 495 S, 512 S, 553 S

Animal diseases: 005 M, 143 M

Arizona: 046 M, 176 M, 180 M, 186 M, 223 M, 267 M, 269 M, 352 M, 353 M, 354 M, 356 M, 364 M, 371 M, 405 M, 460 M, 476 M, 477 M, 483 M, 503 M, 504 M

Arkansas: 087 I

Australia: 056 M, 121 M, 216 M, 500 M, 507 M

Bakersfield: 045 M, 226 M

Berlin: 125 M, 155 M, 308 M

Bibliographies: 063 S, 064 M, 084 S, 119 M, 210 S, 232 M, 328 M, 401 S, 440 M, 499 M, 534 M, 541 M

Biodegradation: 289 M, 306 M, 475 M, 482 M, 511 S

Border irrigation: 286 M, 290 I, 463 M

Buffer zones: 224 M

California: 003 M, 010 M, 016 M, 020 M, 031 I, 041 M, 045 M, 053 M, 055 M, 057 S, 058 M, 068 M, 089 I, 090 M, 099 M, 100 I, 101 M, 116 M, 119 M, 124 M, 127 M, 145 I, 146 M, 147 M, 184 M, 198 M, 207 M, 210 S, 212 M, 213 M, 214 S, 215 M, 219 M, 221 I, 226 M, 233 M, 234 M, 248 M, 259 M, 272 M, 276 M, 284 I, 289 M, 293 M, 296 M,

California--continued:
299 M, 302 M, 303 M, 317 M, 321 M, 322 S, 342 I, 350 M, 355 M, 362 M, 366 M, 374 M, 379 M, 409 M, 410 M, 411 M, 412 M, 422 M, 423 M, 435 M, 439 M, 445 I, 446 M, 468 M, 474 M, 478 M, 484 M, 513 I, 520 M, 533 M, 559 M, 566 I, 568 M

Canada: 001 S, 208 M, 301 I, 333 M, 334 S, 335 M, 421 I

Chicago: 050 S, 360 S, 363 S, 384 S, 391 S, 465 S, 495 S, 512 S, 555 M

China: 291 M, 531 I

Climatic data: 002 M, 016 M, 056 M, 061 M, 080 I, 107 M, 159 S, 211 M, 341 M, 437 M, 514 M

Clogging (soil): 021 M, 044 M, 072 M, 117 I, 134 M, 169 I, 288 M, 297 M, 351 M, 354 M, 400 M, 410 M, 419 M, 449 M, 486 I, 487 M, 548 M

Coliforms: 005 M, 052 M, 095 M, 105 I, 123 M, 130 M, 132 M, 133 M, 135 M, 199 M, 248 M, 276 M, 277 S, 281 M, 299 M, 306 M, 320 M, 343 M, 383 M, 386 M, 398 M, 405 M, 415 M, 427 M, 429 M, 440 M, 476 M, 493 M, 495 S, 519 M

Colorado: 152 M, 252 M, 419 M, 502 S, 529 S

Conferences: 316 M, 347 M

Connecticut: 150 S, 235 S

Costs: 001 S, 009 M, 010 M, 018 M, 020 M, 025 M, 031 I, 035 S, 038 S, 039 M, 051 I, 063 S, 067 S, 074 M, 075 M, 078 M, 079 M, 083 M, 088 I, 091 I, 092 I, 116 M, 122 I, 136 I, 137 I, 146 M, 158 M, 168 I, 170 I, 177 S, 178 I, 184 M, 185 M, 193 I, 200 M, 203 S, 213 M, 214 S, 219 M, 223 M, 234 M, 243 S, 244 S, 265 M, 269 M, 280 M, 287 M, 294 M, 300 M, 305 M, 309 I, 339 M, 352 M, 355 M, 356 M, 371 M, 377 M, 380 M, 388 I, 391 S, 413 S, 421 I, 423 M, 424 I, 429 M, 431 M, 444 M, 450 I, 452 I, 456 M, 463 M, 465 S, 469 M, 477 M, 507 M, 513 I, 518 M, 525 M, 526 M, 531 I, 544 M, 547 S, 556 M, 565 M

Crop response: 070 I, 072 M, 073 I, 262 M, 264 S, 267 M, 285 S, 289 M, 305 M, 308 M, 312 M, 319 M

Czechoslovakia: 197 M

Dairy wastes: 103 I, 114 I, 118 I, 168 I, 201 I, 202 I, 206 I, 208 M, 310 I, 373 I, 418 I, 486 I

Deep percolation: 044 M, 055 M, 068 M, 090 M, 099 M, 101 M, 199 M, 233 M, 238 M, 24[illegible] M, 258 M, 293 M, 343 M, 435 M, 460 M, 468 M, 520 M, 568 M

Denitrification: 105 I, 272 M, 276 M, 343 M, 354 M, 425 M, 429 M, 437 M, 475 M, 476 M, 482 M, 503 M, 504 M, 551 M

Design data: 050 S, 053 M, 057 S, 061 M, 076 M, 093 I, 111 M, 118 I, 148 M, 223 M, 225 S, 237 I, 252 M, 290 I, 298 I, 307 M, 309 I, 325 S, 332 I, 333 M, 381 I, 393 M, 420 M, 444 M, 445 I, 456 M, 471 M, 514 M, 523 M, 525 M, 526 M, 528 I, 546 S, 564 M, 565 M, 567 M

Detergents: 132 M, 134 M, 263 M, 376 M

Dewatering: 546 S

Disinfection: 007 M, 215 M

Dissolved solids: 229 M, 284 I, 419 M, 426 M, 446 M, 459 M, 493 M, 567 M

Economic feasibility: 001 S, 004 M, 006 S, 009 M, 017 M, 034 S, 038 S, 039 M, 042 M, 060 M, 065 M, 066 M, 072 M, 074 M, 076 M, 081 M, 125 M, 156 M, 162 S, 169 I, 188 M, 189 M, 197 M, 203 S, 207 M, 210 S, 211 M, 218 M, 237 I, 253 S, 254 M, 266 M, 271 S, 272 M, 305 M, 318 M, 321 M, 353 M, 357 M, 360 S, 380 M, 384 S, 390 M, 520 M, 528 I, 529 S, 536 M, 555 M, 556 M, 557 M, 558 M

England: 109 M, 113 S, 230 S, 264 S, 315 M, 377 M, 406 S, 413 S, 416 M, 491 S, 530 S, 546 S

Europe: 015 M, 021 M, 023 M, 040 M, 054 M, 075 M, 140 M, 158 M, 190 M, 222 M, 227 M, 378 S, 434 S, 532 M

Evapotranspiration: 002 M, 451 S

Fertilizer value: 006 S, 012 S, 019 S, 026 S, 033 S, 034 S, 035 S, 039 M, 050 S, 057 S, 063 S, 182 S, 290 I, 292 M

Fiber crops: 013 M

Fish farming: 222 M, 291 M, 323 M

Flood irrigation: 002 M, 003 M, 004 M, 011 M, 013 M, 014 M, 018 M, 021 M, 023 M, 025 M, 026 S, 027 M, 028 M, 030 M, 036 M, 042 M, 045 M, 048 I, 052 M, 053 M, 062 M, 066 M, 073 I, 074 M, 088 I, 126 I, 129 M, 131 M, 207 M, 217 S, 240 M, 241 M, 250 M, 254 M, 262 M, 266 M, 267 M, 270 M, 274 M, 280 M, 281 M, 282 M, 286 M, 297 M, 312 M, 325 S, 327 I, 341 M, 488 M, 489 M, 507 M, 560 M, 565 M

Florida: 251 S, 464 M, 521 M, 522 M, 542 M

Food processing wastes: 047 I, 051 I, 070 I, 087 i, 091 I, 092 I, 093 I, 097 I, 114 I, 117 I, 120 I, 122 I, 126 I, 136 I, 137 I, 154 I, 169 I, 179 I, 181 I, 228 I, 332 I, 338 I, 342 I, 349 I, 373 I, 381 I, 382 I, 387 I, 403 I, 404 I, 418 I, 450 I, 452 I, 492 I, 513 I, 516 I, 563 I, 566 I

Forage crops: 018 M, 036 M, 042 M, 045 M, 059 M, 064 M, 068 M, 076 M, 078 M, 082 M, 086 M, 097 I, 102 S, 110 M, 121 M, 167 M, 170 I, 175 M, 186 M, 191 I, 193 I, 195 M, 196 I, 204 I, 212 M, 216 M,

Forage crops--continued:
224 M, 226 M, 228 I, 240 M, 241 M, 255 I, 262 M, 275 I, 327 I, 334 S, 338 I, 394 M, 406 S, 443 S, 488 M, 522 M, 536 M, 538 M, 547 S, 563 I, 568 M

France: 028 M, 083 M

Fresno: 068 M, 350 M

Fruit crops: 081 M, 096 M, 121 M, 127 M, 216 M, 268 M, 566 I

Furrow irrigation: 007 M, 015 M, 022 M, 031 I, 032 M, 047 I, 088 I, 093 I, 094 M, 130 M, 136 I, 142 M, 268 M, 286 M, 305 M, 309 I, 323 M, 330 I, 341 M, 342 I, 348 M, 357 M, 448 M, 486 I, 516 I

Geohydrology: 479 M, 484 M, 510 M

Georgia: 298 I

Germany: 060 M, 086 M, 098 S, 113 S, 125 M, 138 M, 139 M, 155 M, 187 M, 217 S, 224 M, 231 M, 286 M, 290 I, 308 M, 395 S, 396 S, 418 I, 428 M, 451 S

Golf courses: 146 M, 161 M, 184 M, 211 M, 215 M, 423 M, 446 M, 464 M, 508 M

Grain crops: 011 M, 046 M, 106 S, 129 M, 176 M, 195 M, 240 M, 267 M, 291 M, 385 M, 394 M, 454 S, 512 S

Greenbelts: 016 M, 020 M, 049 S, 162 S, 274 M, 284 I, 317 M, 568 M

Groundwater contamination: 089 I, 090 M, 100 I, 101 M, 164 M, 247 M, 275 I, 302 M, 310 I, 320 M, 361 M, 368 M, 391 S, 398 M, 439 M, 457 M, 467 S, 472 M, 506 M, 510 M, 540 S, 541 M

Groundwater movement: 090 M, 198 M, 361 M, 368 M, 374 M, 398 M, 473 M, 506 M

Groundwater recharge: 040 M, 055 M, 058 M, 068 M, 089 I, 100 I, 117 I, 119 M, 124 M, 128 M, 140 M, 145 I, 161 M, 181 I, 190 M, 198 M, 207 M, 213 M, 229 M, 232 M, 234 M, 239 M, 241 M, 247 M, 249 M, 259 M, 269 M, 296 M, 302 M, 312 M, 317 M, 318 M, 321 M, 323 M, 328 M, 340 M, 344 M, 345 M, 350 M, 352 M, 353 M, 355 M, 356 M, 380 M, 385 M, 393 M, 422 M, 431 M, 436 M, 440 M, 441 M, 442 M, 457 M, 458 M, 459 M, 474 M, 476 M, 477 M, 479 M, 506 M, 508 M, 535 M, 550 M

Hawaii: 567 M

Heavy metals: 229 M, 238 M, 264 S, 308 M, 376 M, 391 S, 392 M, 473 M, 490 M, 491 S, 505 M, 511 S, 530 S, 553 S, 562 M

Hertfordshire: 264 S, 491 S, 530 S

Human diseases: 029 M, 034 S, 037 S, 042 M, 052 M, 062 M, 063 S, 066 M, 081 M, 095 M, 098 S, 112 M, 128 M, 130 M, 131 M, 133 M, 134 M, 135 M, 143 M, 145 I, 153 M, 156 M, 161 M, 165 M, 186 M, 187 M, 268 M, 291 M, 326 M, 367 M, 370 M, 378 S, 397 M, 406 S, 428 M, 455 M

Hungary: 453 I

Hydroponics: 402 M

Idaho: 459 M

Illinois: 050 S, 067 S, 360 S, 363 S, 384 S, 391 S, 465 S, 473 M, 495 S, 512 S, 553 S, 555 M

India: 314 M

Indiana: 120 I, 209 I, 462 I, 494 I

Injection wells: 234 M, 431 M, 458 M

Ion exchange: 171 M, 238 M, 272 M, 322 S, 439 M, 453 I, 490 M

Iowa: 047 I, 114 I, 136 I

Israel: 189 M, 241 M, 247 M, 254 M, 281 M, 312 M, 340 M, 390 M, 493 M

Kansas: 165 M

Land reclamation: 214 S, 363 S, 443 S, 465 S, 538 M, 553 S

Legal aspects: 054 M, 187 M, 218 M, 416 M, 438 M, 466 S, 479 M, 517 M

Los Angeles: 055 M, 058 M, 293 M, 296 M, 302 M, 411 M, 422 M, 520 M

Louisiana: 357 M, 426 M

Lubbock: 278 M, 385 M, 457 M

Maryland: 467 S, 480 M

Massachusetts: 499 M

Melbourne: 056 M, 121 M, 500 M, 507 M

Memmingen: 086 M

Mexico: 438 M

Michigan: 049 S, 151 I, 177 S, 179 I, 273 I, 339 M, 414 M, 481 M, 524 I, 557 M, 560 M, 564 M, 565 M

Microbial degradation: 012 S, 183 I, 194 M, 256 M, 277 S, 350 M, 408 I, 492 I

Milwaukee: 012 S

Minnesota: 093 I, 122 I, 169 I, 200 M, 471 M, 551 M

Missouri: 104 S

Monitoring: 151 I, 342 I, 348 M, 349 I, 411 M, 420 M, 468 M, 474 M

Munich: 395 S, 396 S

Muskegon: 339 M, 481 M

Nebraska: 126 I, 192 I

Netherlands: 164 M, 249 M, 304 M

New Hampshire: 554 M

New Jersey: 022 M, 024 S, 025 M, 117 I, 154 I

New Mexico: 115 M

New York: 035 S, 103 I, 111 M, 225 S, 343 M, 345 M, 431 M

New Zealand: 206 I, 228 I, 245 I

Nitrate contamination: 070 I, 109 M, 340 M, 350 M, 439 M, 472 M, 553 S

Nitrification: 026 S, 036 M, 084 S, 109 M, 194 M, 238 M, 405 M, 498 M, 504 M, 511 S, 551 M

North Carolina: 305 M

Nutrient removal: 012 S, 110 M, 192 I, 200 M, 263 M, 394 M, 402 M, 403 I, 410 M, 503 M, 521 M, 551 M

Odor: 018 M, 020 M, 024 S, 031 I, 049 S, 050 S, 058 M, 061 M, 069 M, 089 I, 093 I, 120 I, 122 I, 128 M, 137 I, 150 S, 170 I, 181 I, 189 M, 202 I, 208 M, 215 M, 225 S, 278 M, 311 M, 376 M, 391 S, 406 S, 421 I, 436 M, 522 M, 530 S

Ohio: 038 S, 196 I, 275 I, 306 M, 307 M, 349 I, 437 M, 444 M, 485 M, 558 M

Oklahoma: 263 M

Operation and maintenance: 001 S, 009 M, 025 M, 027 M, 029 M, 035 S, 038 S, 051 I, 054 M, 061 M, 067 S, 069 M, 075 M, 076 M, 077 M, 158 M, 172 M, 177 S, 251 S, 278 M, 296 M, 298 I, 356 M, 388 I, 423 M, 489 M, 500 M, 518 M, 528 I, 554 M, 555 M

Organic loading: 017 M, 031 I, 040 M, 053 M, 091 I, 097 I, 103 I, 118 I, 144 M, 157 I, 166 I, 191 I, 201 I, 260 M, 288 M, 307 M

Overland flow: 077 M, 193 I, 295 I, 338 I, 349 I, 369 M, 381 I, 382 I, 403 I, 404 I, 448 M, 450 I, 492 I, 507 M, 513 I, 527 M, 544 M, 549 M, 550 M, 554 M

Oxidation lagoons: 043 I, 105 I, 108 M, 129 M, 210 S, 245 I, 247 M, 248 M, 281 M, 323 M, 335 M, 362 M, 377 M, 381 I, 390 M, 416 M, 452 I, 564 M

Paris: 338 I, 381 I, 382 I, 403 I, 404 I, 450 I, 492 I

Pathogenic bacteria: 005 M, 037 S, 060 M, 094 M, 095 M, 096 M, 098 S, 123 M, 130 M, 135 M, 143 M, 217 S, 250 M, 279 M, 294 M, 367 M, 370 M, 397 M, 427 M, 428 M, 458 M, 467 S, 532 M, 540 S

Penn State: 393 M, 394 M, 420 M, 425 M, 441 M, 442 M, 443 S, 497 M, 498 M, 514 M, 518 M, 536 M, 538 M, 539 M

Pennsylvania: 043 I, 070 I, 181 I, 295 I, 313 S, 337 S, 375 S, 393 M, 394 M, 420 M, 425 M, 441 M, 442 M, 443 S, 466 S, 497 M, 498 M, 514 M, 518 M, 523 M, 536 M, 537 M, 538 M, 539 M, 544 M

Pesticides: 408 I

Phoenix: 352 M, 353 M, 354 M, 356 M, 476 M, 477 M, 503 M, 504 M

Phosphorus removal: 272 M, 276 M, 343 M, 346 M, 402 M, 403 I, 425 M, 437 M, 450 I, 476 M, 477 M, 487 M, 490 M, 498 M, 551 M, 552 M

Planning: 115 M, 140 M, 227 M, 233 M, 252 M, 335 M, 358 M, 363 S, 412 M, 417 S, 438 M, 463 M, 464 M, 481 M, 485 M, 499 M, 502 S, 519 M, 555 M, 556 M, 557 M, 558 M, 559 M, 567 M

Plant diseases: 359 M, 443 S, 538 M

Plant growth: 059 M, 110 M, 222 M, 270 M, 280 M, 512 S

Poland: 074 M, 076 M, 077 M, 078 M, 079 M, 156 M, 239 M, 257 M, 258 M, 270 M, 292 M, 319 M, 351 M

Potato processing wastes: 387 I, 388 I

Primary effluent: 007 M, 010 M, 011 M, 013 M, 015 M, 022 M, 032 M, 046 M, 094 M, 112 M, 140 M, 152 M, 186 M, 188 M, 226 M, 233 M, 278 M, 289 M, 333 M, 436 M, 447 M, 468 M, 487 M

Public acceptance: 016 M, 049 S, 065 M, 337 S, 364 M, 406 S, 412 M, 478 M, 499 M, 530 S, 557 M, 558 M

Public health regulations: 009 M, 023 M, 029 M, 030 M, 037 S, 041 M, 060 M, 064 M, 072 M, 085 S, 113 S, 127 M, 139 M, 141 M, 152 M, 154 I, 155 M, 161 M, 163 S, 173 M, 180 M, 188 M, 215 M, 218 M, 235 S, 242 S, 250 M, 312 M, 358 M, 366 M, 367 M, 372 M, 379 M, 401 S, 415 M, 430 M, 451 S, 532 M, 533 M, 544 M

Pulp and paper wastes: 151 I, 166 I, 174 I, 183 I, 196 I, 209 I, 255 I, 298 I, 310 I, 327 I, 373 I, 407 I, 494 I, 524 I

Rates of application: 008 M, 010 M, 017 M, 028 M, 039 M, 046 M, 047 I, 048 I, 052 M, 053 M, 061 M, 077 M, 087 I, 103 I, 117 I, 120 I, 121 M, 126 I, 136 I, 145 I, 147 M, 149 S, 151 I, 166 I, 167 M, 168 I, 174 I, 190 M, 194 M, 196 I, 204 I, 209 I, 226 M, 251 S, 255 I, 256 M, 257 M, 264 S, 270 M, 271 S, 275 I, 283 M, 285 S, 293 M, 295 I, 301 I, 307 M, 309 I, 311 M, 319 M, 327 I, 330 I, 332 I, 342 I, 344 M, 345 M, 348 M, 352 M, 360 S, 382 I, 383 M, 385 M, 386 M, 387 I, 388 I, 393 M, 394 M, 407 I, 414 M, 418 I, 422 M, 424 I, 425 M, 441 M, 442 M, 447 M, 452 I, 454 S, 460 M, 462 I, 469 M, 471 M, 474 M, 482 M, 487 M, 489 M, 494 I, 495 S, 498 M, 500 M, 504 M, 508 M, 509 M, 514 M, 518 M, 521 M, 522 M, 523 M, 535 M, 539 M, 550 M, 552 M, 562 M, 566 I, 568 M

Raw sewage: 002 M, 004 M, 005 M, 023 M, 028 M, 030 M, 062 M, 064 M, 106 S, 127 M, 198 M, 246 M, 248 M, 253 S, 256 M, 257 M, 262 M, 270 M, 277 S

Recreational facilities: 116 M, 119 M, 211 M, 274 M, 299 M, 317 M, 321 M, 328 M, 379 M, 401 S, 412 M, 445 I, 542 M

Recycling nutrients: 057 S, 063 S, 064 M, 067 S, 078 M, 079 M, 102 S, 108 M, 112 M, 125 M, 140 M, 142 M, 149 S, 150 S, 153 M, 159 S, 163 S, 176 M, 180 M, 182 S, 203 S, 214 S, 222 M, 225 S, 230 S, 269 M, 334 S, 336 S, 360 S, 375 S, 396 S, 434 S, 461 S, 466 S, 470 S, 475 M, 515 S, 543 S, 561 S

Reviews: 006 S, 008 M, 015 M, 018 M, 021 M, 029 M, 034 S, 071 M, 107 M, 138 M, 183 I, 190 M, 239 M, 243 S, 261 I, 265 M, 282 M, 283 M, 316 M, 322 S, 326 M, 359 M, 366 M, 367 M, 369 M, 370 M, 371 M, 399 M, 401 S, 407 I, 409 M, 430 M, 433 M, 435 M, 438 M, 448 M, 456 M, 460 M, 479 M, 486 I, 496 S, 502 S, 515 S, 517 M, 525 M, 526 M, 532 M, 534 M, 537 M, 545 M, 549 M, 554 M, 560 M, 564 M

Rhode Island: 427 M

Salinity: 055 M, 059 M, 153 M, 184 M, 233 M, 255 I, 284 I, 292 M, 322 S, 357 M, 376 M, 392 M, 426 M, 427 M, 453 I, 472 M, 483 M, 493 M, 563 I

San Antonio: 011 M, 082 M, 326 M

San Francisco: 016 M, 020 M, 116 M

Santee: 248 M, 299 M, 321 M, 412 M

Seabrook Farms: 117 I, 154 I,

Septic tanks: 036 M, 147 M, 220 M, 288 M, 297 M, 311 M, 361 M, 400 M, 447 M

Silviculture: 273 I, 455 M, 535 M, 536 M, 537 M, 538 M

Sludge disposal: 024 S, 034 S, 037 S, 041 M, 049 S, 050 S, 067 S, 084 S, 085 S, 086 M, 098 S, 104 S, 129 M, 149 S, 150 S, 162 S, 163 S, 182 S, 214 S, 230 S, 231 M, 235 S, 242 S, 243 S, 244 S, 251 S, 253 S, 264 S, 271 S, 277 S, 310 I, 313 S, 322 S, 325 S, 336 S, 337 S, 363 S, 365 S, 375 S, 378 S, 384 S, 395 S, 396 S, 413 S, 434 S, 465 S, 466 S, 467 S, 496 S, 501 S, 502 S, 515 S, 543 S, 546 S

Soil chemical properties: 006 S, 008 M, 036 M, 142 M, 144 M, 236 M, 243 S, 249 M, 257 M, 258 M, 290 I, 292 M, 306 M, 314 M, 329 M, 346 M, 351 M, 368 M, 389 M, 432 M, 433 M, 443 S, 448 M, 449 M, 453 I, 467 S, 470 S, 483 M, 488 M, 490 M, 491 S, 497 M, 503 M, 505 M

Soil contamination: 042 M, 052 M, 308 M, 383 M, 408 I, 433 M, 455 M, 501 S

Soil microbiology: 044 M, 359 M, 409 M, 420 M, 432 M, 433 M, 439 M, 447 M, 451 S, 497 M, 511 S

Soil physical properties: 004 M, 008 M, 010 M, 014 M, 019 S, 025 M, 026 S, 027 M, 044 M, 075 M, 131 M, 144 M, 174 I, 183 I, 257 M, 258 M, 285 S, 292 M, 308 M, 320 M, 329 M, 346 M, 354 M, 361 M, 374 M, 389 M, 392 M, 419 M, 420 M, 433 M, 435 M, 464 M, 494 I, 497 M, 504 M, 506 M, 533 M, 536 M, 548 M, 550 M, 560 M

Soil types: 011 M, 014 M, 017 M, 023 M, 024 S, 026 S, 047 I, 048 I, 083 M, 088 I, 089 I, 101 M, 104 S, 107 M, 124 M, 138 M, 139 M, 159 S, 164 M, 167 M, 170 I, 171 M, 194 M, 199 M, 202 I, 209 I, 242 S, 243 S, 245 I, 246 M, 271 S, 277 S, 283 M, 289 M, 307 M, 320 M, 329 M, 339 M, 341 M, 374 M, 393 M, 400 M, 404 I, 407 I, 408 I, 419 M, 435 M, 437 M, 483 M, 488 M, 507 M, 521 M, 524 I, 552 M, 462 M

South Africa: 071 M, 266 M, 519 M

Southeast U.S.: 182 S

Southwest U.S.: 009 M, 014 M, 175 M, 274 M, 372 M, 472 M

Soviet Union: 113 S, 246 M, 250 M, 279 M, 320 M, 341 M, 386 M, 398 M, 399 M, 488 M

Spray disposal: 039 M, 077 M, 092 I, 114 I, 120 I, 151 I, 171 M, 192 I, 202 I, 219 M, 276 M, 298 I, 327 I, 333 M, 335 M, 465 S, 513 I, 524 I, 527 M, 542 M, 554 M

Spreading basins: 058 M, 099 M, 100 I, 101 M, 124 M, 234 M, 241 M, 247 M, 293 M, 317 M, 354 M, 356 M, 398 M, 410 M, 411 M, 454 S, 472 M, 477 M, 533 M

Sprinkler irrigation: 016 M, 020 M, 069 M, 070 I, 080 I, 083 M, 085 S, 086 M, 087 I, 088 I, 091 I, 097 I, 102 S, 103 I, 106 S, 107 M, 112 M, 118 I, 122 I, 123 M, 125 M, 128 M, 133 M, 137 I, 138 M, 141 M, 142 M, 147 M, 148 M, 150 S, 155 M, 166 I, 167 M, 168 I, 169 I, 170 I, 174 I, 176 M, 179 I, 180 M, 181 I, 183 I, 184 M, 187 M, *Sprinkler irrigation--continued:* 189 M, 190 M, 191 I, 195 M, 196 I, 197 M, 200 M, 201 I, 204 I, 206 I, 208 M, 209 I, 212 M, 213 M, 215 M, 217 S, 224 M, 226 M, 227 M, 229 M, 237 I, 245 I, 273 I, 275 I, 279 M, 282 M, 286 M, 295 I, 296 M, 301 I, 304 M, 311 M, 330 I, 332 I, 339 M, 357 M, 358 M, 362 M, 369 M, 378 S, 383 M, 387 I, 414 M, 424 I, 445 I, 446 M, 462 I, 463 M, 464 M, 469 M, 471 M, 481 M, 486 I, 497 M, 514 M, 516 I, 518 M, 522 M, 523 M, 539 M, 552 M, 560 M

Subsurface drainage: 205 M, 351 M, 386 M

Subsurface irrigation: 138 M, 139 M, 410 M, 428 M, 529 S

Surveys: 014 M, 030 M, 073 I, 082 M, 109 M, 119 M, 158 M, 162 S, 177 S, 182 S, 187 M, 192 I, 220 M, 210 S, 213 M, 219 M, 279 M, 280 M, 282 M, 283 M, 294 M, 303 M, 304 M, 344 M, 355 M, 366 M, 414 M, 478 M, 484 M, 510 M, 516 I, 544 M, 545 M

Suspended solids: 045 M, 116 M, 157 I, 273 I, 349 I, 377 M, 423 M, 494 I, 528 I, 542 M

Sweden: 470 S

Tannery wastes: 301 I, 373 I, 418 I, 421 I

Tennessee: 461 S

Tertiary treatment: 045 M, 074 M, 116 M, 299 M, 300 M, 345 M, 352 M, 362 M, 377 M, 416 M, 431 M, 436 M, 441 M, 444 M, 459 M, 460 M, 492 I, 508 M, 542 M

Texas: 002 M, 007 M, 011 M, 013 M, 027 M, 032 M, 082 M, 129 M, 144 M, 172 M, 185 M, 188 M, 278 M, 280 M, 325 S, 326 M, 328 M, 338 I, 367 M, 381 I, 382 I, 385 M, 403 I, 404 I, 450 I, 457 M, 489 M, 492 I

Tile drainage: 205 M, 473 M

Trickling filter effluent: 057 S, 348 M, 402 M, 458 M

Tucson: 046 M, 176 M, 180 M, 269 M, 364 M, 371 M, 405 M, 460 M, 483 M

United States: 001 S, 017 M, 021 M, 029 M, 030 M, 039 M, 040 M, 054 M, 073 I, 080 I, 084 S, 113 S, 118 I, 141 M, 149 S, 159 S, 163 S, 220 M, 232 M, 253 S, 282 M, 300 M, 400 M, 407 I, 479 M, 496 S, 515 S, 516 I, 517 M, 525 M, 526 M, 528 I, 532 M, 545 M, 556 M

Utah: 148 M

Vegetable crops: 007 M, 022 M, 035 S, 037 S, 062 M, 066 M, 072 M, 081 M, 095 M, 096 M, 123 M, 131 M, 132 M, 133 M, 134 M, 135 M, 156 M, 188 M, 217 S, 246 M, 250 M, 279 M, 285 S, 304 M, 358 M, 451 S, 547 S, 563 I

Vegetation damage: 094 M, 171 M, 200 M, 426 M, 540 S

Vineland: 022 M, 024 S, 025 M

Virginia: 174 I

Viruses: 248 M, 299 M, 364 M, 368 M, 370 M, 374 M, 386 M, 397 M, 412 M, 428 M, 429 M, 440 M, 473 M, 509 M, 519 M, 541 M, 567 M

Washington: 097 I, 193 I, 195 M, 203 S, 204 I, 332 I, 361 M, 388 I

Wastewater disposal: 027 M, 040 M, 041 M, 051 I, 054 M, 068 M, 069 M, 071 M, 078 M, 079 M, 082 M, 083 M, 087 I, 106 S, 107 M, 108 M, 110 M, 111 M, 119 M, 121 M, 125 M, 132 M, 139 M, 141 M, 144 M, 146 M, 154 I, 155 M, 156 M, 172 M, 173 M, 176 M, 180 M, 185 M, 191 I, 193 I, 203 S, 205 M, 206 I, 216 M, 222 M, 227 M, 231 M, 232 M, 237 I, 260 M, 283 M, 287 M, 291 M, 314 M, 326 M, 389 M, 432 M, 466 S, 468 M, 469 M, 475 M, 480 M, 515 S, 533 M, 535 M, 545 M, 549 M, 555 M

Wastewater treatment: 043 I, 058 M, 091 I, 096 M, 098 S, 099 M, 105 I, 108 M, 111 M, 115 M, 143 M, 146 M, 147 M, 148 M, 152 M, 153 M, 155 M, 197 M, 199 M, 220 M, 249 M, 263 M, 295 I, 303 M, 326 M, 331 M, 333 M, 364 M, 365 S, 369 M, 371 M, 379 M, 380 M, 390 M, 399 M, 405 M, 409 M, 417 S, 425 M, 430 M, 441 M, 442 M, 444 M, 445 I, 448 M, 480 M, 481 M, 484 M, 485 M, 496 S, 498 M, 499 M, 500 M, 510 M, 527 M, 531 I, 537 M, 549 M, 557 M, 558 M, 559 M

Water management (applied): 339 M, 344 M, 385 M, 485 M, 523 M, 556 M, 559 M

Water quality data: 055 M, 099 M, 109 M, 114 I, 124 M, 126 I, 149 S, 157 I, 165 M, 178 I, 192 I, 204 I, 212 M, 236 M, 245 I, 260 M, 265 M, 338 I, 347 M, 366 M, 382 I, 404 I, 411 M, 446 M, 458 M, 500 M, 534 M

Water quality standards: 080 I, 081 M, 085 S, 090 M, 100 I, 127 M, 145 I, 178 I, 185 M, 259 M, 303 M, 315 M, 316 M, 324 M, 340 M, 355 M, 379 M, 392 M, 416 M, 453 I, 459 M, 527 M

Water reuse: 003 M, 005 M, 056 M, 059 M, 065 M, 073 I, 108 M, 111 M, 115 M, 158 M, 160 I, 161 M, 165 M, 172 M, 173 M, 175 M, 178 I, 185 M, 208 M, 210 S, 211 M, 213 M, 216 M, 218 M, 221 I, 223 M, 229 M, 231 M, 232 M, 236 M, 240 M, 252 M, 254 M, 260 M, 261 I, 263 M, 265 M, 274 M, 284 I, 294 M, 296 M, 300 M, 302 M, 303 M, 316 M, 321 M, 323 M, 324 M, 328 M, 331 M, 340 M, 347 M, 364 M, 372 M, 438 M, 456 M, 478 M, 520 M, 535 M

Winter storage: 301 I, 421 I, 436 M, 471 M, 524 I, 565 M

Wisconsin: 012 S, 105 I, 157 I, 166 I, 168 I, 201 I, 202 I, 262 M, 309 I, 330 I, 348 M

SECTION I

ABSTRACTS PRIOR TO 1941

001 S THE UTILIZATION OF SEWAGE SLUDGE AS FERTILIZER: A REPORT OF THE COMMITTEE ON SEWAGE DISPOSAL APHA

Anonymous
Sewage Works J., 9: 861-912, 1937.

Descriptors: Canada, United States, Economic feasibility, Operation and maintenance, Costs.

A comprehensive report resulting from a survey of sludge disposal practices in the United States and Canada. Data were furnished by State sanitary engineers, sewage works operators, and municipal officials. Discussed in connection with use of sludge as fertilizer are soil fertilization, fertilizer value, use in mixed fertilizers, tonnage of sludge available, types of sludge, and comparisons of sludge from different treatment processes. Results of sludge utilization on many different crops are presented and general conclusions based on the results of the survey are given.

002 M IRRIGATION WITH SEWAGE

Anonymous
Eng. News-Rec., 121: 821, 1938.

Descriptors: Texas, Raw sewage, Evapotranspiration, Flood irrigation, Climatic data.

A storage lake and land irrigation solved the sewage disposal problem at Kingsville, Texas. In this region of low rainfall and high evaporation, suitable streams for the disposal of sewage are practically nonexistent. The distribution and disposal system is described. The storage lake makes the system quite flexible. Disposal operations continue even when irrigation is not in progress.

003 M BIOFILTRATION EFFLUENT USED FOR IRRIGATION AT SANTA PAULA
Anonymous
Eng. News-Rec., 125: 834, 1940.

Descriptors: California, Flood irrigation, Water reuse.

Effluent from a biofiltration sewage treatment plant serving 12,000 residents in Santa Paula, California, is used to irrigate orchard lands adjacent to that city. The city is proud of its attractive and useful plant which is capable of converting sewage into irrigation water.

004 M SEWERAGE AND SEWAGE PURIFICATION, 2nd ed.
Baker, M. M.
New York, D. Van Nostrand Company, 1905. 153 p.

Descriptors: Raw sewage, Economic feasibility, Soil physical properties, Flood irrigation.

The author devotes five pages to the subject of "Broad Irrigation or Sewage Farming." He states that the biggest problem is the need for land, about an acre per 100 people. Both price and availability of land are obstacles, as well as soil type. Soil should be fairly light and porous--wet, cloying soil can be used sometimes, and cultivation with sewage can improve its characteristics. The use of sewage for irrigation also has political and economic problems and the method of sewage irrigation is best suited for arid regions.

005 M EFFECT ON ANIMAL HEALTH OF FEEDING SEWAGE
Crawford, A. B., and A. H. Frank
Civil Eng., 10: 495-496, 1940.

Descriptors: Pathogenic bacteria, Animal diseases, Coliforms, Water reuse, Raw sewage.

A study was conducted at the U. S. Department of Agriculture's Beltsville Research Center in which swine and cattle remained in good condition after a severe six-month feeding period including raw sewage, treatment plant effluent, and sludge. This study concluded that virulent bacteria were not present in sufficient concentration in the incoming sewage, effluent, or sludge of this sewage treatment plant to cause disease in susceptible animals. These test animals were subjected to a more severe exposure to effluent than would normally be expected to occur.

006 S ADAPTABILITY OF SEWAGE SLUDGE AS A FERTILIZER

DeTurk, E. E.
Sewage Works J., 7: 597-610, July 1935.

Descriptors: Fertilizer value, Anaerobic digestion, Economic feasibility, Soil chemical properties, Reviews.

A significant historical review of sewage utilization is made. Comparisons of chemical composition and fertilizer value are made between sludge produced by the activated sludge process and digested or Imhoff sludge. Digested sludge is also compared to farm manure. Methods of sludge utilization are discussed. Future development of sludge-processing methods may well result in the production of sludge with increased fertilizer value. Even though sludge may be low in fertilizer value, its organic content should not be overlooked as a soil-conditioning agent.

007 M TREATMENT REQUIRED FOR SEWAGE REUSED FOR IRRIGATION PURPOSES

Diehl, Paul A.
Sewage Works J., 8: 502-503, August 1936.

Descriptors: Texas, Primary effluent, Furrow irrigation, Vegetable crops, Disinfection.

About 100 cities, most of which are in California and Texas, use sewage for irrigation purposes. Oil and grease should be removed, as well as all solids that might settle out in the irrigation ditches. For use on garden crops, the sewage should be sterilized and filtered.

008 M SEWAGE DISPOSAL BY IRRIGATION

Eddy, Harrison, and Leonard Metcalf
In: American Sewerage Practice Vol. III, 3rd ed., New York, McGraw-Hill, 1935. Chap. 9, p. 233-252.

Descriptors: Reviews, Soil physical properties, Soil chemical properties, Rates of application.

The physical, chemical and biological processes of the soil in treating sewage effluent have been widely used. Initial settling is preferred to prevent clogging of the soil and rates of 18 feet per year have been recorded. Examples of sewage farms in Europe and America are given. In 1910, Berlin had over 43,000 acres in use for sewage disposal. Pasadena had its farm in use since 1887.

009 M EXPERIENCES WITH SEWAGE FARMING IN SOUTHWEST UNITED STATES
Ehlers, V. M., F. C. Roberts, Jr., and E. A. Reinke
Amer. J. Pub. Health, 25: 119-127, 1935. Abstr., Sewage Works J., 7: 320-322.

Descriptors: Southwest U. S., Economic feasibility, Operation and maintenance, Costs, Public health regulations.

This article discusses the sewage disposal (using land systems) problems and advantages in three states: Texas, Arizona, and California. The article discusses the cost of the systems, the length of operation, the type of crops which were grown, and the revenue from them. Suggestions were given by Texas engineers. All data necessary was given for the State of Arizona including rainfall, temperature, population, average sewage flow, average type of sewage, etc. Ways of dispelling odors were discussed. Health aspects, danger of polluting groundwater, previous treatment and crop yields were discussed to a great extent. A great deal was said about California's health laws (as to what crops could be legally irrigated with sewage water and the type of sewage that could be used) and their effect on the number of land systems used.

010 M SIMPLE APPLICATIONS OF FUNDAMENTAL PRINCIPLES OF SEWAGE TREATMENT
Gillespie, C. G.
Sewage Works J., 1: 68-69, 1928.

Descriptors: California, Primary effluent, Rates of application, Soil physical properties, Costs.

The author describes two cases where expensive disposal alternates were avoided by conversion to land application. At Carmel, California a flow of 0.05 mgd from a septic tank was diverted to 3,000 sq ft of sand beds. The coarse sand (0.3 mm effective size) is raked after inundation for a week and no ponding develops. At Vacaville, California 0.125 mgd of septic tank effluent was passed over a field of heavy clay prior to ponding. The 8 acre field was graded to a 1 percent slope and a thick stand of grass grew immediately. Only about 10 percent of the effluent applied over 8 months appeared as runoff.

011 M SEWAGE IRRIGATION IN TEXAS
Goodwin, Earl H.
Pub. Works, 66: 23-24, March 1935.

Descriptors: San Antonio, Texas, Primary effluent, Soil types, Flood irrigation, Grain crops.

Since 1900, San Antonio has utilized a part of its sewage effluent to irrigate up to 3500 acres. At present, about 47 plants in Texas use irrigation as a means of treatment and disposal. Spray, border, and furrow methods are used to irrigate grains, grasses, cotton, alfalfa, nuts, and citrus. Porous sandy soils seem to be most suitable. Careful supervision is required so that soil type and crops form a compatible combination for the efficient utilization of the effluent.

012 S SEWAGE SLUDGE AS A FERTILIZER
Harper, Horace J.
Sewage Works J., 3: 683-687, 1931.

Descriptors: Milwaukee, Wisconsin, Anaerobic digestion, Fertilizer value, Nutrient removal, Microbial degradation.

Fertilizing value of sewage sludge depends upon its source and the sewage treatment process. The nitrogen content may be quite different for sludges obtained from Imhoff tank and activated sludge processes. Activated sludge may contain 5 to 6 percent total nitrogen, with total phosphoric acid content of approximately 3 percent. Sludge from Imhoff tanks seldom contains more than 2.5 percent nitrogen and 2 percent phosphoric acid.

Cites the city of Milwaukee's experience with "Milorganite" produced from activated sludge and several experiments concerned with fertilizer value of sludge. Liquid sludge has considerably more fertilizer value than dried sludge since much of the nutrient content drains away in the drying process.

013 M SEWAGE IRRIGATION AS A METHOD OF DISPOSAL
Harrell, Riley B.
In: Proc. 21st Tex. Water Works Sewerage Short Sch., December 1939. p. 121-123. Abstr., Sewage Works J., 12: 1019, 1940.

Descriptors: Texas, Primary effluent, Flood irrigation, Fiber crops.

The author describes sewage irrigation as practiced by the city of Munday, Texas. Use of row crops is recommended for better weed control. Cotton is most satisfactory crop. In 1934, 24 acres of irrigated land produced 23 bales of cotton. Dry land produced less than one-third bale per acre of poorer quality cotton. Serious problem of effluent disposal has been solved by irrigation.

014 M SEWAGE IRRIGATION AS PRACTICED IN THE WESTERN STATES
Hutchins, W. A.
U.S. Dept. Agr. Tech. Bull. 675, Washington, D.C., March 1939. 60 p.

Descriptors: Southwest U.S., Flood irrigation, Surveys, Soil physical properties, Soil types.

A survey was conducted in 1934 and 1935 and rechecked in 1937 on 125 sites in 15 western states where irrigation with sewage was being practiced. For the 113 sites in which sewage irrigation was continuing in 1937, factors discussed included crops irrigated, ownership and operation, public health regulations, salts in the effluent, sewage water rights, and economic feasibility of sewage irrigation. Other factors included soil types (predominantly higher soils), proximity of dwellings, effects on the soil, and long term environmental effects. For the 12 sites where irrigation was discontinued, reasons were given for discontinuance, including unsuitable soil, limited lands, availability of substitute water supplies, change in location of treatment plants, and unsatisfactory management.

015 M SEWAGE DISPOSAL PRACTICE IN EUROPE
Hyde, C. G.
West. Constr. News, 4: 345-352, July 1929.

Descriptors: Europe, Primary effluent, Furrow irrigation, Reviews.

The author reports on inspection tour of 28 sewage treatment plants in Great Britain and Germany. The treatment processes observed are described. A number of plants employed "broad irrigation" as a means of treatment. The sewage of Berlin, Paris, and Milan is used to irrigate crops.

016 M THE BEAUTIFICATION AND IRRIGATION OF GOLDEN GATE PARK WITH ACTIVATED SLUDGE EFFLUENT
Hyde, Charles
Sewage Works J., 9: 929-941, November 1937.

Descriptors: San Francisco, California, Public acceptance, Climatic data, Greenbelts, Sprinkler irrigation.

Lack of available fresh water caused San Francisco to turn to other sources for park irrigation. At first raw sewage was used, but with development of the area came complaints and a search for new sources of water. The water is from the sewage of about 10-15,000 people and amounts to about 500,000 gpd, and undergoes activated sludge treatment and chlorination. Average rainfall in the area is 22 inches, 85 percent of which falls from November to March. The average temperature is 56°, ranging from 68° in September to 45° in January.

017 M TREATMENT ON NATURAL SOIL
Imhoff, Karl, and Gordon Fair
In: Sewage Treatment, New York, John Wiley and Sons, Inc., 1940. Chap. 7, p. 108-118.

Descriptors: Economic feasibility, Rates of application, Soil types, Organic loading, United States.

When land is available cheaply, land treatment of sewage can be economical. Rates of application vary from 750 gpd per acre to 24,000 gpd per acre, depending on the soil type, cover crop, and land use. Use of sand beds with secondary effluent can take loadings of 800,000 gpd per acre.

018 M UTILIZATION OF DOMESTIC SEWAGE AND INDUSTRIAL WASTES BY BROAD IRRIGATION
Kreuz, C. A.
Sewage Works J., 8: 348-349, March 1936.

Descriptors: Forage crops, Flood irrigation, Costs, Odor, Reviews.

The author discussed the use of sewage for agricultural purposes. He suggested that, in order to produce maximum yield of agricultural products the sewage from as many as 80 inhabitants can be distributed on an acre, if the grass is cut three or four times, and the sewage evenly distributed over the year. The fertilizing constituents can be used to greatest advantage when the sewage is artificially sprinkled but this method has the highest operating cost and requires the largest amount of land.

Two methods of irrigation are discussed. In ordinary broad irrigation, land is divided into areas about 1.25 acres in size. The disadvantages are: the use of agricultural machinery is difficult; smoothing of the surface is expensive; too much of the land is used for roads, dikes and ditches; cultivation of cereals has not proved satisfactory; and odors during the summer cannot be entirely avoided.

In another method of irrigation, the water is held on plots of land 6 to 30 acres in size by dikes about 20 inches high. These plots are covered with sewage to a depth of 8 to 12 inches and allowed to stand from 3 to 6 days in summer and about a week in winter. The water remaining after that time is drained off through ditches. The distribution of land with at least a two percent slope has also proved very satisfactory.

019 S USE OF SLUDGE AS FERTILIZER

Maloy, Thomas P.
Sewage Works J., 3: 485-487, July 1931.

Descriptors: Anaerobic digestion, Soil physical properties, Fertilizer value.

Sludge does not have the high fertilizing value of commercial fertilizers. Experiments indicated that it is very effective in improving the physical condition of the soil: "Where the ground was hard and compact before, it is now soft and resilient. It has a certain amount of spring to it." "The whole texture of the soil was improved and made more pliable."

020 M SEWAGE TREATMENT FOR OBTAINING PARK IRRIGATING WATER

McQueen, Frank
Pub. Works, 64: 16-17, 1934. Abstr., Sewage Works J., 6: 145-146.

Descriptors: San Francisco, California, Greenbelts, Sprinkler irrigation, Odor, Costs.

Golden Gate Park (1,013 acres), San Francisco, was originally irrigated with sewage from an outfall sewer traversing the park. This was soon discontinued because of objectionable odors. The purchase of potable *water proved too costly. A new sewage treatment plant, completed in 1932 and employing the activated-sludge process, supplies 1 mgd for irrigation of the Park. The water is clear, odorless, and completely satisfactory for the purpose. Odors and suspended matter are so completely removed that the excess plant effluent is used for lakes and waterfalls.*

021 M SEWERAGE AND SEWAGE DISPOSAL
Metcalf, Leonard, and Harrison P. Eddy
New York, McGraw-Hill, 1922. 598 p.

Descriptors: Europe, Clogging (soil), Reviews, Flood irrigation, United States.

Part of this textbook describes sewage irrigation in Britain, France, Germany and the U.S. Although sewage does have valuable fertilizer value, it is most valuable for its water content, as sewage is 99.9 percent water. Unfortunately, sewage also contains fat and soap which are harmful to land, causing clogging of the soil. This condition can be overcome with the use of screening and sedimentation before application to the land. Sewage irrigation in the U.S. has not been used on a large scale, but numerous small-scale operations have been used for many years around the country, especially in Southern California. Although satisfactory, none of the operations has been an unqualified success. One city, San Antonio, Texas, is described as having a system which pumps the sewage 12 miles from the city to a 6,700-acre privately owned tract.

022 M SEWAGE FARM DISPLACES FILTER BEDS AT VINELAND, N.J.
Mitchell, George A.
Eng. News-Rec., 104: 65, January 1930.

Descriptors: Vineland, New Jersey, Primary effluent, Vegetable crops, Furrow irrigation.

Vineland was one of the first cities to adopt sewage irrigation of crops as a means of disposal. The raw sewage was piped a distance of 2.5 miles to a sandy area where a settling tank and sludge-drying beds were built. The effluent was used to irrigate 50 acres of recently cleared river sand. The second year produced good yields of sweet potatoes, sweet corn, eggplant, and rhubarb on this previously sterile soil with the use of no fertilizer except sewage.

023 M OBSERVATIONS ON SEWAGE FARMING IN EUROPE
Mitchell, George A.
Eng. News-Rec., 106: 66-69, January 1931.

Descriptors: Europe, Raw sewage, Soil types, Flood irrigation, Public health regulations.

Sewage farms were visited in Berlin and other German cities, Paris, Moscow, Edinburgh, and four towns in England. Some of the cities of Germany have used this form of sewage disposal for over 60 years, and very successfully. Cases are cited where very poor sandy land has been converted to good, productive farmland by sewage irrigation. Details of sewage farm operations at Berlin, Paris, and Moscow are given. In England, sewage irrigation of crops is decreasing due to growth of cities, and because suitable areas for expansion of the farms are difficult to find. Tighter, less sandy soils than on the continent require larger areas for suitable sewage farming practices. Experience has shown that sewage farming poses no serious threat to the public health.

024 S SLUDGE DISPOSAL AT A SEWAGE IRRIGATION FARM
Mitchell, George A.
Eng. News-Rec., 107: 57, July 1931.

Descriptors: Vineland, New Jersey, Soil types, Sludge disposal, Odor.

The author describes a method of disposing of sludge-bearing sewage as practiced at Vineland, New Jersey. The sludge is pumped onto a field prepared with deep furrows. Immediately upon drying, the sludge is plowed under, and the field prepared to receive another sludge treatment. Once the sludge is plowed under, odor and insect nuisances are eliminated. The surface soil proved to be an excellent purifier.

025 M MUNICIPAL SEWAGE IRRIGATION
Mitchell, George A.
Eng. News-Rec., 119: 63-66, July 1937.

Descriptors: Vineland, New Jersey, Flood irrigation, Soil physical properties, Costs, Operation and maintenance.

A sewage irrigation farm in use since 1928 at Vineland, New Jersey, provides disposal facilities for a population of 8,000 and aids crop production in poor soil. A detailed description of the operating methods is given. Distribution system details include land slope and flow, land preparation, and crops grown. Revenue and cost data are included.

026 S THE VALUE OF RAW SEWAGE SLUDGE AS FERTILIZER
Muller, J. F.
Soil Sci., 28: 423-432, 1929.

Descriptors: Fertilizer value, Soil physical properties, Soil types, Flood irrigation, Nitrification.

Several samples of dried fresh sewage sludge were analyzed, and pot experiments carried out to determine the fertilizer value of such material. The analyses showed considerable potential plant food is present. The carbon-nitrogen ratio was narrowed to below eight by the addition of available nitrogen, markedly increasing the fertilizer value of the sludge. A phosphate supplement appears to be necessary for good plant growth; and a potash supplement, in small quantities, seems desirable. The dried sludge alone, with no mineral supplements, when applied to turf grown on sand gave a good stand of grass and prevented its dying off. Dried fresh sludge applied to a sandy soil materially increased its water-holding capacity, a most desirable result on soils of this type. Although the experiments reported did not indicate a need for using lime with the sludge, lime almost certainly would be required after several years' continuous sludge application.

027 M SEWAGE IRRIGATION AS A METHOD OF DISPOSAL
Peurifoy, R. L.
In: Proc. 21st Tex. Water Works Sewerage Short Sch., December 1939.
p. 115-121. Abstr., Sewage Works J., 12: 1018-1019.

Descriptors: Texas, Flood irrigation, Operation and maintenance, Wastewater disposal, Soil physical properties.

Constituents in sewage that are beneficial to soil are listed, as well as certain others that are objectionable. Results of irrigation with sewage at Kingsville, Texas are described. Methods of application are varied. Condition of subsoil, as well as texture of surface layer, are important considerations. Reservoir for storage of at least three months' supply is recommended.

Sewage disposal by irrigation is safe, effective, and economical. Cities should seriously consider irrigation as a possible method of disposal.

028 M SEWAGE PURIFICATION IN THE PARISIAN AREA. CONSTRUCTION OF A BIOLOGICAL TREATMENT WORKS AT ACHERES
Pouquet, F.
Travaux (Paris), 79: 87-95, March 1938. Abstr., Sewage Works J., 11: 719-720, July 1939.

Descriptors: France, Raw sewage, Rates of application, Activated sludge effluents, Flood irrigation.

A network of sewers is under construction which will terminate in the agricultural area of Acheres. Sewage of Paris is presently spread on farms in four different regions, at an average rate of 132 mgd. Future growth estimates predict increased volume to as much as 634 mgd. Due to limited areas for expanding farm operations, biological treatment is being planned to take care of excess flow. Sewage irrigation has proved satisfactory. Liquid sludge from the new activated sludge treatment plant will be disposed of on farmlands.

029 M SEWAGE IRRIGATION
Rafter, George W.
U.S. Geol. Surv. Water-Supply Pap. 3, Washington, D.C., 1897. 100 p.

Descriptors: United States, Reviews, Human diseases, Public health regulations, Operation and maintenance.

The author presents the method of sewage irrigation as a method which is not new. His purpose is to point out to American farmers and to municipal authorities the benefits of this use of sewage. It is especially useful in the arid West and has been used in Cheyenne, Wyoming since 1883, and is in use at about 60 installations in the U.S. Problems of disease are described as minimal with proper care, and crops fit for human consumption can be grown. Descriptions are given of various methods of sewage irrigation along with descriptions of foreign operations in Germany, France and England.

030 M SALVAGE OF SEWAGE STUDIES
Rawn, A. M.
Civil Eng., 4: 471-472, 1934.

Descriptors: United States, Surveys, Public health regulations, Raw sewage, Flood irrigation.

A report of the ASCE Joint Committee of the Sanitary Engineering and Irrigation Division, based on questionnaires mailed to Public Health Directors of the 48 states and the District of Columbia, to learn the extent of sewage use for irrigation in each of the states, the influence of such use on public health, and the standards that should be prescribed and enforced if water and fertilizer reclaimed from sewage are to be used in the production of foodstuffs to be eaten raw, to be cooked, to be used as fodder crops, or to be used in the irrigation or fertilization of public grounds.

Nine of the forty states responding acknowledged experience with sewage irrigation. Four claimed illnesses could be traced directly to such use; one claimed cattle pastured on raw sewage-irrigated fields developed poorly and were infected with a disease that rendered the meat unfit for human consumption.

Others indicated no difficulty, probably because of the manner of irrigation and the nature of the crops grown. Many of the states without experience indicated that such practice would be prohibited in any form on vegetables or fruits to be eaten raw. The majority expressed a willingness to allow its use on fodder crops or on lawns and parks.

Other results of the survey are also discussed.

031 I THE PREVENTION OF ODOR NUISANCE IN THE DISPOSAL OF CREAMERY WASTES BY TREATMENT WITH CHLORINE PRELIMINARY TO BROAD IRRIGATION

Reinke, E. A.

Sewage Works J., 1: 128-132, January 1928.

Descriptors: California, Furrow irrigation, Odor, Costs, Organic loading.

A creamery in Wasco, California, was disposing of 125,000 gpd by ridge and furrow irrigation. Despite a moderate loading of 8,000 gpd odors were being produced. Chlorination of the wastewater with a dosage of 20 mg/l prior to irrigation relieved the odor problems without detrimental effects on the corn crop. Chlorination raised the cost of disposal by $1.50 per day to $7.15 per day.

032 M IRRIGATION WITH SEWAGE EFFLUENTS
Riney, W. A.
Sewage Works J., 1: 108, 1928.

Descriptors: Abilene, Texas, Primary effluent, Furrow irrigation.

Abilene, Texas, disposes of effluent from septic tanks by contracting with farmers to use the effluent for irrigation of row crops.

033 S SEWAGE SLUDGE AS FERTILIZER
Rudolfs, Willem
Soil Sci., 26: 455-458, 1928.

Descriptors: Anaerobic digestion, Aerobic digestion, Fertilizer value.

The nitrogen content of sewage sludge varies with the type of treatment. Aerobically and anaerobically treated sewage sludges contain about 5 and 2.25 percent nitrogen, respectively. Only one sewage treatment plant markets its sludge on a large scale; at a number of places the sewage sludge is given away or sold for a small nominal sum. An estimated 150,000 to 200,000 tons of nitrogen are lost annually. Analysis of sludges from a number of sewage plants indicates that 8,000 to 10,000 tons nitrogen per year could be saved.

034 S SLUDGE DISPOSAL AND FUTURE TRENDS
Rudolfs, Willem, and E. J. Cleary
Sewage Works J., 5: 409-428, May 1933.

Descriptors: Reviews, Economic feasibility, Human diseases, Sludge disposal, Fertilizer value.

Present methods of sludge handling and disposal are discussed. The need for further development is stressed. Sludge as a fertilizer is discussed from the standpoint of fertilizing value, preparation of fertilizer, and economic and hygienic considerations. Fertilizer production may be profitable only for the large plants. Small plants usually must dispose of sludge material locally as a market develops. Dewatering and incineration offer promise as a means of ultimate disposal.

035 S SEWAGE SLUDGE AS FERTILIZER

Skinner, John F.
Sewage Works J., 4: 279-282, March 1932.

Descriptors: New York, Operation and maintenance, Costs, Vegetable crops, Fertilizer value.

Sludge from four Imhoff tanks at Rochester, New York is utilized as fertilizer for gardens, shrubs, lawns, and local farm crops. Details of the operation are described, and sales data are shown. Liquid sludge has much greater nutrient value than dried sludge. Consideration is given to dispensing liquid sludge, thus eliminating cost of constructing and operating drying beds.

036 M EFFECT OF IRRIGATION WITH SEWAGE EFFLUENT ON THE YIELDS AND ESTABLISHMENT OF NAPIER GRASS AND JAPANESE CANE

Stokes, W. E., W. A. Leukel, and R. M. Barnette
Agron. J., 22: 540-548, 1930.

Descriptors: Septic tanks, Nitrification, Flood irrigation, Soil chemical properties, Forage crops.

Septic tank effluent was used to irrigate forage crop plants for four years. Yields were higher from the sewage-irrigated plots than from nonirrigated and the city water-irrigated plots. Analyses of typical sewage effluent showed the presence of considerable quantities of nitrogen compounds. Analyses of soil following irrigation showed only slight increases in nitrogen content.

037 S PUBLIC HEALTH SIGNIFICANCE OF SEWAGE SLUDGE WHEN USED AS A FERTILIZER

Tanner, Fred W.
Sewage Works J., 7: 611-617, July 1935.

Descriptors: Sludge disposal, Pathogenic bacteria, Vegetable crops, Human diseases, Public health regulations.

The application of sewage sludge to soil on which vegetables, which may be eaten raw, are grown should be practiced with caution. While longevity of pathogenic bacteria in sludge would probably be greatly influenced by the nature of the sludge and the conditions under which it is stored *and handled, sufficient data have been recorded to indicate the presence of viable Bacterium typhosum cells in sludge. At best, the sludge should be added to the soil in the late fall, winter, or early spring. Wolman's advice, probably sound, is that sludge not be added to growing crops. Sanitary districts and others concerned with the sale of sewage sludge to farmers might well consider the health hazards involved.*

038 S THE ECONOMIC PREPARATION AND SALE OF DIGESTED SLUDGE AS COMMERCIAL FERTILIZER
Tatlock, M. W.
Sewage Works J., 4: 519-524, 1932.

Descriptors: Ohio, Economic feasibility, Costs, Anaerobic digestion, Operation and maintenance.

The author describes in detail the operation of the Dayton, Ohio sewage treatment plant. Cost of operation and income from sales are given. Results show promise. Sludge can be successfully marketed.

039 M THE USE OF SEWAGE EFFLUENTS IN AGRICULTURE
Veatch, N. T., Jr.
In: Modern Sewage Disposal, Pearse, L. (ed.), New York, Fed. Sewage Works Ass., 1938. Chap. 16, p. 180-190.

Descriptors: United States, Spray disposal, Economic feasibility, Costs, Fertilizer value, Rates of application.

Sewage effluent by irrigation was found to be used by at least 115 cities for reasons of economy and for crop benefits. Three examples of sewage effluent are given at costs of about $10.00 per mg (1935 costs). The fertilizer value of the effluent is emphasized, along with the importance of using scientific methods of choosing sites and loading rates.

040 M INVESTIGATIONS ON THE PURIFICATION OF BOSTON SEWAGE
Winslow, C. E. A., and E. B. Phelps
U.S. Geol. Surv. Water-Supply Pap. 185, Washington, D.C., 1906. 163 p.

Descriptors: United States, Groundwater recharge, Wastewater disposal, Organic loading, Europe.

One method of sewage disposal consists of distributing the sewage over broad areas and allowing the liquid to recharge the groundwater. The method has been widely used in Europe since the sixteenth century. Conditions for "sewage farming" are specially favorable in the arid portions of the western United States. Plants in Utah, California, Wyoming are mentioned. In areas selected for sewage application, the soil should be light and the subsoil sandy or gravelly to obtain suitable recharge rates. Recharge rates in England range between 0.006 and 0.046 feet per day, and in Germany between 0.006 and 0.021 feet per day.

041 M CALIFORNIA REGULATES USE OF SEWAGE ON CROP LAND
Wright, C. T.
Sewage Works J., 6: 162, January 1934.

Descriptors: California, Public health regulations, Sludge disposal, Wastewater disposal.

Under California's public health act, the disposal of sewage, sewage effluent or sludge for irrigation or fertilizing purposes is permitted only to those who hold a permit issued by the State Board of Public Health, and subject to regulations adopted by that board on May 27, 1933. These regulations are discussed.

SECTION II

ABSTRACTS 1941 THRU 1950

042 M GRAZING OF CATTLE ON SEWAGE FARMS AND DISPOSAL WORKS
Abbot, A. L.
Pub. Health (S. Africa), p. 76-88, March 1948. Abstr., Sewage Works J., 21: 185-186, January 1949.

Descriptors: Flood irrigation, Human diseases, Economic feasibility, Forage crops, Soil contamination.

Quoting from the abstract: "It is the consensus that consumption of sewage effluents by cattle has no harmful effect on milk production or disease incidence, and introduces no possibility of milk comtamination except indirectly from unhygienic dairy procedures. The positive advantages of irrigating grazing land with sewage include utilization of valuable fertilizing material and irrigating water as well as providing a satisfactory sewage disposal method that produces revenue to partially offset sewage works costs."

Procedures followed at the Cape Town sewage works are given.

043 I SOME RIGHTS AND WRONGS OF CANNERY WASTE TREATMENT
Allison, Claire, and Christian Subert
Water Sewage Works, 95: 227-230, June 1948.

Descriptors: Pennsylvania, Wastewater treatment, Anaerobic conditions, Spray disposal, Oxidation lagoons.

After screening and settling, wastes from a Hanover, Pennsylvania, cannery are piped to lagoons. Soda ash and sodium nitrate are added to prevent anaerobic decomposition in the lagoons. The water is then piped to fields where it is successfully used as spray irrigation water throughout the entire year.

044 M EFFECT OF MICROORGANISMS ON PERMEABILITY OF SOIL UNDER PROLONGED SUBMERGENCE

Allison, L. E.
Soil Sci., 63: 439-450, 1947.

Descriptors: Clogging (soil), Soil microbiology, Soil physical properties, Deep percolation.

The permeability of continuously submerged soils usually decreases slightly at first and then increases appreciably as the entrapped air is removed by solution in the percolate. Subsequently, a large reduction in permeability occurs until the soil virtually seals up.

Sterile permeability tests conducted to determine the cause of decreased permeability under prolonged submergence gave no evidence of soil aggregate breakdown due to purely physical causes. The reduced permeability appears to be due entirely to microbial sealing. The soil pores probably become clogged with the products of growth, cells, slimes or polysaccharides. If any of the observed reduction in permeability was due in part to disintegration of soil aggregates, the dispersion is believed to be due to biological causes, that is, the attack of microorganisms on the organic materials which bind soil into aggregates.

045 M COMBINING OLD AND NEW IN SEWAGE DISPOSAL

Anonymous
Eng. News-Rec., 126: 811-812, 1941.

Descriptors: Bakersfield, California, Suspended solids, Flood irrigation, Forage crops, Tertiary treatment.

Using a recently developed flocculation-clarifier unit, which gives high efficiency in the removal of suspended solids, the City of Bakersfield, California supplements this pretreatment of its sewage with irrigation of 600 acres of pasture land.

046 M SEWAGE FARMING AT TUCSON

Anonymous
Sewage Works J., 18: 1211, November 1946.

Descriptors: Primary effluent, Rates of application, Tucson, Arizona, Grain crops.

Average of flow of 4 mgd is used to irrigate about 300 acres of city-owned land with primary treatment effluent. Crops of oats, barley, ensilage are rotated on the land.

047 I DISPOSAL OF CANNING PLANT WASTES BY IRRIGATION
Bolton, P.
In: Proc. 3rd Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1947.
p. 272-281.

Descriptors: Food processing wastes, Furrow irrigation, Iowa, Soil types, Rates of application.

Two systems disposing of cannery wastewater by ridge and furrow irrigation are described. At Hampton, Iowa, a soil system consisting of 6 feet of silt loam has been in operation since 1934. Loadings are 134,000 gad of wastewater and 660 lb BOD/acre/day.

At Waverly, Iowa, the soil system consists of a medium black friable loam, underlain with limestone that arises at some points to within a few feet of the surface. The liquid loading is 96,300 gad and the solids loading is 1,040 lb/acre/day.

048 I GRAPE STILLAGE DISPOSAL BY INTERMITTENT IRRIGATION
Coast Laboratories
San Francisco, Calif., Prepared for the Wine Institute, June 1947.

Descriptors: Flood irrigation, Rates of application, Anaerobic digestion, Soil types.

Stillage from conventional stills should be spread on land at a rate of 100,000 gad followed by a 6 day drying period. This results in a recommended loading rate of 3.7 in./wk. About twice as much drying time is required for stillage from pomace stills, therefore a loading rate of 1.8 in./wk is recommended. Soil on which untreated stillage is applied may be temporarily toxic to plants due to ferrous ion salts, acetates, and other products of anaerobic digestion. During experiments conducted to establish the foregoing criteria, loadings of 78,400 gad were used for 54 days on sandy loam soil. Thus a 5.5 safety factor is used in the recommended 14,300 gad loading.

049 S LIQUID SLUDGE - THE VITAMIN B FERTILIZER
Damoose, N.
Sewage Works Eng., 12: 308-312, 1941.

Descriptors: Michigan, Greenbelts, Odor, Public acceptance, Sludge disposal.

The sale of liquid sludge has been promoted at Battle Creek, Michigan. After successful trials on the plant grounds, a truck was fitted with a 600-gallon tank for delivery of liquid digested sludge to the public. Use of this material on lawns produced "astounding" results. Odor and appearance nuisances were overcome by wetting down with sprinklers following application. In addition to the plant food value, the author believes Vitamin B plays an important role and discusses this in some detail.

050 S EXPERIENCE OF CHICAGO, ILL., IN THE PREPARATION OF FERTILIZER
Dundas, William A., and C. P. McLaughlin
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 69: 80-102, 1943.

Descriptors: Sludge disposal, Chicago, Illinois, Fertilizer value, Odor, Design data.

In the sludge disposal of The Sanitary District of Chicago (Ill.) a method has been worked out by a chain of experiments to dewater and heat dry activated sludge for use as fertilizer material or for incineration. The principles of design are indicated from the heat standpoint together with the control of odors. A typical heat balance is presented, with a discussion of the relative merits of various fuels. At the Southwest Works a combination of power generation with heat drying has been successfully used.

051 I INDUSTRIAL WASTES--CANNING INDUSTRY
Eldridge, Edward F.
Ind. Eng. Chem., 39: 619-624, 1947.

Descriptors: Food processing wastes, Costs, Wastewater disposal, Operation and maintenance.

Canners operate on a seasonal basis. Their wastes consist largely of washings from the preparation of products for canning. Waste volume and characteristics vary widely with the type of products packed. The material in the wastes consists largely of organic solids in suspension which cause objectionable conditions when they decompose. Effective screening should be a common practice with all cannery wastes. This may be followed by chemical precipitation, sedimentation, biological filtration, or lagooning, or a combination of these, depending upon the degree of treatment necessary. The required treatment is established by governmental agencies in each case.

Lagooning and irrigation are desirable, in that the method completely eliminates stream pollution. Operating methods and cost figures are presented.

052 M BACTERIAL CONTAMINATION OF TOMATOES GROWN IN POLLUTED SOIL

Falk, L. L.
Amer. J. Pub. Health, 39: 1338-1342, October 1949.

Descriptors: Coliforms, Soil contamination, Human diseases, Flood irrigation, Rates of application.

The concentration of coliform bacteria on the surfaces of tomatoes grown in polluted soil indicated no abnormal gross contamination. Even when sprayed with fecal suspensions, surface coliform counts were no greater after one month than on control tomatoes. The failure to find Salmonella cerro seven days after its application to growing tomatoes upholds the contention that organisms of fecal origin will not be present in sufficient number to cause gross contamination. It is felt that tomatoes grown on soils receiving night soil or sewage sludge fertilization would yield fruit which, if eaten raw, would not be likely vectors for the transmission of human bacterial enteric diseases.

053 M LAND DISPOSAL OF SEWAGE

Gray, H. F., and W. O'Connell, Jr.
Sewage Works J., 16: 729-740, April 1944.

Descriptors: California, Design data, Organic loading, Flood irrigation, Rates of application.

Land application of sewage effluents can be done with different objectives. If the objective is an agricultural operation, the loading rates should be 2,000 to 3,000 gpd per acre depending on the crop. The area for irrigation should be planted to one crop and a second area for excess effluent should be set aside. Three installations using municipal effluent in California are described.

054 M AGRICULTURAL UTILIZATION OF DOMESTIC SEWAGE IN EUROPE AND U.S.A.

Halamek, Ferdinand
Bull. Czechoslovak Academy Agriculture (Prague), 22: 396-402, 1948.
Biol. Abstr., 23: 3092, 1949.

Descriptors: Europe, United States, Wastewater disposal, Operation and maintenance, Legal aspects.

The present status of sewage irrigation and the utilization of fertilizing ingredients in sewage and sewage sludge in Europe and U.S.A. is presented. Germany uses sewage irrigation and often overlooks the hygienic problem. In Britain the use of sewage as a fertilizer is decreasing. In the U.S.A. sewage irrigation is practiced only in the southwestern states and, there, hygienic regulations are severe. Directions are given for proper management of sewage irrigation.

055 M LOS ANGELES CONSIDERS RECLAIMING SEWAGE WATER TO RECHARGE UNDERGROUND BASINS

Hedger, Harold E.
Civil Eng., 20: 323-324, 1950.

Descriptors: Groundwater recharge, Deep percolation, Salinity, Water quality data, Los Angeles, California.

Reclamation of wastewater from sewage constitutes an important potential source of water for spreading and recharge of underground basins. Experimental tests have shown that the percolated effluent is bacteriologically safe within a depth of 7 feet from the ground surface. Irrespective of the groundwater recharge, it is proposed as a means of creating a freshwater barrier to seawater encroachment.

056 M SEWAGE RECLAMATION AT MELBOURNE, AUSTRALIA
Hyde, C. G.
Sewage Ind. Wastes, 22: 1013-1015, August 1950.

Descriptors: Forage crops, Water reuse, Melbourne, Australia, Climatic data.

Geological, climatic, and population statistics at Melbourne, Australia are given. A description of the sewage farm facilities is included. These facilities handle an average load of 58 mgd. Grass filtration is used and cattle are raised or fattened on the plots.

057 S SEWAGE PLANT SELLS SLUDGE AND EFFLUENT
Jackson, Leon W.
Eng. News-Rec., 139: 56-58, 1947.

Descriptors: California, Design data, Recycling nutrients, Trickling filter effluent, Fertilizer value.

Trickling filters, 175 ft in diameter, feature the design of a new sewage treatment plant for the city of Riverside, California. The plant is so arranged that the entire flow through the plant is by gravity. Treated effluent will be used for irrigation purposes and dried sludge will be sold for fertilizer. Complete design and engineering data for the new plant are given.

058 M RECLAMATION OF WATER FROM SEWAGE AND INDUSTRIAL WASTES IN LOS ANGELES COUNTY
Ludwig, Russell G.
Sewage Ind. Wastes, 22: 289-295, March 1950.

Descriptors: Groundwater recharge, Odor, Los Angeles, California, Wastewater treatment, Spreading basins.

Discusses the use of reclaimed waters for augmenting underground water resources, including beneficial use for industrial and agricultural purposes, which indirectly aids in building up groundwater reserves by curtailing existing draft on the underground basins. Excellent opportunities for industrial use exist in Los Angeles County, and such projects are under current study.

The direct recharge of underground basins through the use of natural sand filters seems especially significant for the following reasons:

1. The sand filters not only serve as the means of recharge but also act as a final check on water quality.

2. The vast undergound water storage basins are most advantageously used in a storage capacity; thus, they allow intermittent operation of reclamation plants and at the same time maintain a firm water supply.

3. Finally, water so returned to the underground can be used for any beneficial purpose, including domestic consumption.

059 M EFFECT OF SEWAGE WATER ON THE YIELD AND QUALITY OF GRASSLAND

Maloch, M.
Sbornik Ceskoslovenske Akademie Aemedelskych (Prague), 19: 57-107, 1946. Abstr., Soils Fert., 13: 364(2021), 1950.

Descriptors: Salinity, Forage crops, Water reuse, Plant growth.

Application of sewage water for 3 years to grassland raised the hay yield by 132.9 percent and the yield of crude protein by nearly 300 percent. Additions of superphosphate, Ca and K salts to the sewage waters gave even higher increases. There was evidence of residual action of N from the sewage, and its effect in increasing the resistance of the grasses to summer drought was very marked.

060 M THE AGRICULTURAL USE OF SEWAGE

Muller, Wilhelm
Wasser Boden (Hamburg), p. 124, 1949. Abstr., Sewage Ind. Wastes, 22: 589, April 1950.

Descriptors: Germany, Public health regulations, Water management (applied), Pathogenic bacteria, Economic feasibility.

During recent years, the agricultural use of sewage has often been discussed in Germany, with no final answer being reached on this important question. Public health requires hygienic sewage disposal, but local authorities alone cannot solve the problem. It is a task for the state organization, especially in densely settled countries.

Water conservation has become more important and water use must be regulated. Within this water planning, sewage has its own part. In particular, the agricultural use of sewage by different technical means may appreciably increase a country's productivity. For this purpose, sewage must be fully treated and freed of pathogenic organisms.

The humus matter and the manure value of sewage should be used in agriculture to compensate for the organic matter exported from the country as food. Sewage disposal into the ocean only "manures" the sea water. Treated sewage should be discharged into rivers only in such volume as is necessary to manure the rivers for fishing industries.

061 M EMERGENCY LAND DISPOSAL OF SEWAGE

O'Connell, William J., Jr., and Harold Farnsworth Gray
Sewage Works J., 16: 729-746, July 1944.

Descriptors: Design data, Operation and maintenance, Rates of application, Odor, Climatic data.

The shifting of population during the war years brought on overcrowding in certain localities and overloading of waste treatment and disposal facilities. Land disposal should be considered as an emergency measure where these conditions exist. At the same time, the authors feel that land treatment or land disposal of sewage is legitimate, effective, practical, and worthy of consideration, especially for small cities in arid or semi-arid regions. They point out the basic principles, adaptability, and limitations, and present the fundamental factors in successful design and operation. Land disposal may have as its primary purpose an agricultural operation or a disposal operation. Over-irrigation must be avoided. Intermittent application followed by cultivation is recommended for good soil condition and weed control. If properly operated, no appreciable odors should result from using a well-clarified effluent.

062 M A NOTE ON CONSUMPTION OF VEGETABLES GROWN ON SEWAGE IRRIGATED LAND

Orenstein, A. J.
Sewage Works J., 20: 954-955, September 1948.

Descriptors: Raw sewage, Flood irrigation, Vegetable crops, Human diseases.

This article relates the experience of two mine labor communities with consumption of vegetables grown on sewage irrigated lands.

063 S UTILIZATION OF SEWAGE SLUDGE AS FERTILIZER
Pearse, Langdon, and A. H. Niles, et al.
Fed. Sewage Works Ass., Champaign, Ill., Manual of Practice No. 2, 1946. 120 p.

Descriptors: Recycling nutrients, Bibliographies, Costs, Fertilizer value, Human diseases.

The major topics in the manual are: Fertilizer Requirements of Soils; Fertilizer Characteristics of Sewage Sludge; Effects of Sewage Treatment Practices on Fertilizing Elements in Sludge; Processing Sludge for Use as Fertilizer; Application of Sludge as Fertilizer; Hygienic Aspects of Sludge Utilization as Fertilizer; Prices, Marketing, and Economic Considerations. A closing chapter includes conclusions and recommendations relative to sludge utilization. The bibliography contains 251 entries.

064 M SALVAGE OF SEWAGE
Rawn, A. M., William E. Stanley, Earnest Boyce, R. F. Goudey, and E. A. Reinke
Trans. Amer. Soc. Civil Eng., 107: 1652-1687, 1942.

Descriptors. Raw sewage, Forage crops, Recycling nutrients, Bibliographies, Public health regulations.

This comprehensive report considers the salvage of products from sewage: "Water, fertilizer, gas, grease, and such other materials as may be separated from sewage in the treatment plant or elsewhere and used." Public Health considerations are listed as important guidelines. Discussions cover the reclamation and use of water from sewage, both for irrigation and industry, and the reclamation and use of fertilizer from sewage. A bibliography with 65 entries is included.

065 M BLENDING OF SEWAGE EFFLUENT WITH NATURAL WATERS PERMITS REUSE
Rawn, A. M.
Civil Eng., 20: 324-325, 373, 1950.

Descriptors: Water reuse, Public acceptance, Economic feasibility.

Reclaiming water from sewage is not a new idea; the reuse of sewage or effluent for agriculture, industry, and other purposes has been well established.

Water reclamation from sewage depends on sound engineering principles. Public acceptance of unrestricted reuse of sewage waters often depends on the inclusion of a "natural" purification process, such as blending with lake, river, or underground waters.

066 M NEW VIEWPOINTS ON THE AGRICULTURAL UTILIZATION OF SEWAGE

Reinhold, F.
Gesundh. Ing. (Munich), 69: 296-302, 1948. Pub. Health Abstr., 31: 545.

Descriptors: Economic feasibility, Vegetable crops, Human diseases, Flood irrigation, Spray irrigation.

Studies were made to determine the relative fertilizing value of settled and biologically treated sewage. It was found that treatment improved the availability of nutrient materials other than nitrogen, and it also increased the formation of humus in the soil. Spray irrigation allows bacteria to be carried by spray and air movement for distances of 800 meters. They are soon killed by sunlight. The eggs of worms in digested sludge were not viable. Raw sewage should not be used for irrigation of any kind, and only biologically treated sewage should be used for irrigating vegetables.

067 S DISPOSAL OF LIQUID SLUDGE AT KANKAKEE, ILLINOIS

Schriner, Phillip J.
Sewage Works J., 14: 876-878, April 1942.

Descriptors: Costs, Illinois, Sludge disposal, Operation and maintenance, Recycling nutrients.

Cost figures show that liquid sludge disposal by tank truck delivery constitutes a considerable saving over operation and maintenance of sludge drying beds. It also eliminates the severe operating difficulties of sludge drying beds in the winter months. The use of liquid sludge to fertilize lawns will be promoted, and the practice should show a considerable profit to the city over past experience with sludge drying beds.

068 M SEWAGE RECLAMATION AT FRESNO, CALIFORNIA

Segel, A.
Sewage Ind. Wastes, 22: 1011-1012, August 1950.

Descriptors: Fresno, California, Forage crops, Deep percolation, Groundwater recharge, Wastewater disposal.

The city of Fresno owns and operates a municipal farm, 1,292 acres in area, where the treated sewage effluent is used for the irrigation of crops. In addition to 600 acres of grassland, the water is used to irrigate such forage crops as alfalfa, sudan grass, and kaffir corn. A herd of over 600 fine Hereford cattle are maintained on the farm. For the fiscal year ending June 30, 1949, the city realized an operating profit of $9,346. In 1921, the city owned only 812 acres, and disposal of sewage effluent created a serious problem with a high water table only about 2 feet below the surface. Lawsuits were filed by adjacent landowners for waterlogging and flooding adjacent lands. To correct this situation, some of the land was lagooned, and 9 wells were installed from 200 to 300 feet deep with no perforation of the casing less than 100 feet. Water from the wells was diverted to the Fresno Irrigation District for use in its system. Increased irrigation agriculture and installation of many wells in the area have helped to improve the groundwater level and facilitate the percolation of plant effluent into the underground basin.

069 M PROBLEMS IN SEWAGE FARMING

Shreier, Franz
Ber. Abwassertech. Ver. (Munich), 2: 118, 1950. Abstr., Sewage Ind. Wastes, 25: 241, February 1953.

Descriptors: Operation and maintenance, Wastewater disposal, Odor, Sprinkler irrigation.

The problems considered are pretreatment, changes in farming methods, zoning of urban areas, hygiene, biology, and economics. Pretreatment is considered to be imperative. Changes in farming methods may involve new capital investments. Sewage farming should not be permitted near water treatment plants. Odors may interfere in urban areas. Spraying onto grazing areas is hygienically, biologically, and economically the best means of sewage utilization.

070 I SOME RIGHTS AND WRONGS OF CANNERY WASTE TREATMENT
Siebert, C. L., and C. Allison
Water Sewage Works, 95: 227-230, June 1948.

Descriptors: Pennsylvania, Food processing wastes, Sprinkler irrigation, Crop response, Nitrate contamination.

The Hanover Canning Company in York County, Pennsylvania, discharges 0.19 to 0.44 mgd of cannery waste to a spray irrigation site. The system consists of portable pipe on 175 acres of grass. Tests were conducted to determine the effect of high nitrate concentrations on the crop. There was no effect up to 60 mg/L, stunted growth but no burning at 80 mg/L, and severe burning at 100 mg/L.

071 M SEWAGE DISPOSAL BY IRRIGATION
Spencer, B. R.
Pub. Health (S. Africa), 7: 15-28, October 1943. Abstr., Sewage Works J., 16: 655-657, May 1944.

Descriptors: Wastewater disposal, Forage crops, Reviews, South Africa.

Land disposal is necessary in South Africa since few places permit effluent to be discharged to streams. Reviews history of land disposal. First recorded sale of effluent for irrigation was at Bromford, England, in 1869.

Water requirements of different crops are considered. Over-irrigation has resulted in raised water tables and "brackish" soil conditions. Deep plowing has been employed to help alleviate the situation.

Italian rye grass has been found to be satisfactory. Its several advantages are enumerated.

072 M AGRICULTURAL USES OF RECLAIMED SEWAGE EFFLUENTS--
A DISCUSSION
Travaini, Dario
Sewage Works J., 20: 33-35, January 1948.

Descriptors: Public health regulations, Vegetable crops, Crop response, Economic feasibility, Clogging (soil).

Chlorinated effluent is often purer bacteriologically than irrigation water found in Arizona and should be viewed as a valuable resource. However, its use for vegetables which are not heat processed, such as lettuce or tomatoes, is frowned upon by state health boards. It has been shown that sewage effluent produces superior crop yields and that soil blocking by high sodium ratios can be neutralized by a lowering of pH.

073 I INDUSTRIAL USES OF RECLAIMED SEWAGE EFFLUENTS
Veatch, M. T.
Sewage Works J., 20: 3-11, January 1948.

Descriptors: Water reuse, Surveys, Flood irrigation, Crop response, United States.

Although the article is about industrial uses of water, the author includes a list of places where sewage effluent is used, and this includes 124 examples of agricultural usage and 11 truly industrial uses.

074 M THE NEED FOR PRETREATMENT OF SEWAGE UTILIZED FOR AGRICULTURAL PURPOSES
Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 23: 162, May 1949. Abstr., Sewage Works J., 21: 1110, January 1949.

Descriptors: Tertiary treatment, Flood irrigation, Costs, Economic feasibility, Poland.

The agricultural use of sewage results in a high degree of treatment, along with the advantages of fertilization and enrichment of soil with humus. Reasons for preferring clarified sewage effluent for irrigation are listed and discussed. Two disadvantages resulting from pretreatment are removal of fertilizer materials and increase in cost of operation. If the sludge is recovered and used as a fertilizer, more of the fertilizing value will be utilized.

075 M DISADVANTAGES AND ADVANTAGES OF SEWAGE DISPOSAL IN CONNECTION WITH AGRICULTURAL UTILIZATION
Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 23: 198, 1949. Abstr., Sewage Ind. Wastes, 22: 578-579, April 1950.

Descriptors: Europe, Wastewater reuse, Operation and maintenance, Soil physical properties, Costs.

Agricultural use of sewage in Europe dates back to 1559. Rapid growth of cities and restricted land areas later led to overloading and unsatisfactory results. Where adequate areas were available, the results were satisfactory.

Disadvantages include large land area needed, suitable soil porosity required, must be located downstream from water source, and pumping cost if it must be transported some distance.

A major benefit is to the economy of an area. Arid acres can be made productive. Other advantages are the fertilizer value and increasing humus content of the soil. Gravity flow to the field is best.

076 M SEWAGE FARMING AT OSTROW WIELKOPOLSKI

Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 23: 387, 1949. Abstr., Sewage Ind. Wastes, 22: 971-972, August 1950.

Descriptors: Poland, Forage crops, Economic feasibility, Operation and maintenance, Design data.

Disposal by sewage farming dates back to 1911 at fields 2.5 miles from the city. The farm operation is described in detail, giving acres used, daily flow, treatment processes, and hay and silage yields. The farms are well managed, show a definite profit to the city, and benefit the local farmers by providing them with excellent hay.

077 M MODERN METHODS IN THE AGRICULTURAL UTILIZATION OF SEWAGE

Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 23: 298, 1949. Abstr., Sewage Ind. Wastes, 22: 969-970, November 1949.

Descriptors: Poland, Operation and maintenance, Rates of application, Spray disposal, Overland flow.

Natural sloping terrain of at least two percent should be used. Loading rates are 25 to 50 acres per 1,000 population. Large areas are required.

Any method normally used for applying irrigation water can be employed. Spraying has many advantages, but a clarified effluent is required. Fish ponds or forested areas may be utilized to take care of the excess flows.

078 M ECONOMICS OF SEWAGE DISPOSAL IN CONNECTION WITH AGRICULTURAL UTILIZATION
Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 24: 193, May 1950. Abstr., Sewage Ind. Wastes, 22: 1508, December 1950.

Descriptors: Wastewater disposal, Poland, Costs, Recycling nutrients, Forage crops.

European experience with sewer farms is summarized. Developments leading to the distribution of sewage on irrigation fields and factors affecting their cost of operation are considered. Hay yields were increased 5-8 fold. Increases in other crops are also reported.

079 M EFFECT OF GEOGRAPHICAL FACTORS ON THE WIDESPREAD AGRICULTURAL USE OF SEWAGE
Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 24: 407, November 1950. Abstr., Sewage Ind. Wastes, 23: 941, July 1951.

Descriptors: Poland, Costs, Recyling nutrients, Wastewater disposal.

Surface irrigation in England is not feasible because of high annual rainfall, small irrigable areas, large concentrations of population, and low nutrient value of effluents. Sewage irrigation has developed rapidly in central Europe due to inadequate rainfall, more permeable soils, and high nutrient content of sewage.

High temperatures and low rainfall in the western U.S. favor irrigation with clean water or sewage. The potential for sewage irrigation in Poland is excellent. Gravity flow to the farm is favored, although moderate pumping costs may be permissible.

080 I AGRICULTURAL USES OF RECLAIMED SEWAGE EFFLUENT
Wilcox, L. V.
Sewage Works J., 20: 24-33, January 1948.

Descriptors: United States, Water quality standards, Sprinkler irrigation, Climatic data.

Especially in arid regions, the use of sewage efluent as irrigation water is to be recommended. Three chemical groupings to be concerned with are trace elements, cations and anions, and total salts. Boron is the most important trace element to be concerned with as many plants are injured by concentrations of around 1 ppm. Under cations and anions, a good rule to remember is that hard waters make soft land, thus soft water is not desired for irrigation. Generally sewage effluents are quite suitable for irrigation purposes; toxic materials can usually be diluted to safe limits.

081 M POLLUTION OF IRRIGATION WATERS
Wright, C. T.
Sewage Ind. Wastes, 22: 1403-1412, November 1950.

Descriptors: Vegetable crops, Fruit crops, Human diseases, Water quality standards, Economic feasibility.

The report emphasizes the importance of irrigation for the economic and agricultural development of the western states. In this connection, pollution of irrigation waters is a problem that must be solved in some areas to permit maximum utilization of water resources. Opinions differ among health authorities as to the health hazards associated with the use of polluted water for irrigating edible crops. This is reflected in the lack of uniform requirements or standards covering such use. As no widely accepted requirements or standards exist for the quality of irrigation waters or the streams from which they are drawn, there is a definite need for basic data on which reasonable requirements can be based. No conclusions can be drawn from current studies relating to the pollution of irrigation waters, and health authorities agree that more research is needed to develop methods which will permit full utilization of existing and potential irrigation waters. These studies should include epidemiological investigations to determine the relationship between the use of truck crops exposed to polluted irrigation waters and enteric infections. There appears to be some agreement regarding the use of well-oxidized and adequately disinfected effluents for irrigating fruits and vegetables. In the absence of widely accepted requirements or standards, health authorities must require a high degree of treatment.

SECTION III

ABSTRACTS 1951 THRU 1955

082 M COMMENTS ON SEWAGE IRRIGATION
Anonymous
Sewage Ind. Wastes, 25: 233-234, February 1953.

Descriptors: Surveys, Wastewater disposal, San Antonio, Texas, Forage crops.

A survey of the opinions of users of sewage for irrigation. Four farm owners from around the San Antonio, Texas area give statements on the effect of sewage on their crops or pastures.

083 M SPRAY IRRIGATION
Anonymous
Tech. de l'Eau (Brussels), 8(92): 23-28, 1954. Water Pollut. Abstr., 28: 224(1490), 1955.

Descriptors: Soil types, Costs, France, Sprinkler irrigation, Wastewater disposal.

Spray irrigation is useful, in that it involves less wastage of water than methods previously used, requires no land preparation, leaves more room for the crops, can be used on undulating ground, and can be used in very permeable soils where other methods are useless. The higher expense is largely compensated by considerably lower maintenance costs. Its use in France is discussed.

084 S SEWAGE SLUDGE FOR SOIL IMPROVEMENT
Anderson, Myron S.
U.S. Dept. Agr., Wash., D.C., Circ. No. 972. 1955. 27 p.

Descriptors: Sludge disposal, Nitrification, Bibliographies, Anaerobic digestion, United States.

Chemical compositions of sludges variously prepared in different parts of the United States are reported. Only 18 to 25 percent of the nitrogen present in digested sludges is normally nitrified during a 16-week period. Activated sludges show nitrification values of 50 to 60 percent for a similar period. The bibliography has 41 entries.

085 S HYGIENE OF IRRIGATION AND THE USE OF SEWAGE RESIDUES
Anonymous
Staedteh. (Hamburg), 6: 259-260, 1955. Water Pollut. Abstr., 29: 244(1348), 1956.

Descriptors: Public health regulations, Sludge disposal, Sprinkler irrigation, Water quality standards, Europe.

A draft is given of a proposed standard (DIN 19650) dealing with requirements for water used for irrigation and with the use of sewage and sludge in agriculture.

086 M THE SEWAGE UTILIZATION PLANT AT MEMMINGEN
Bachmann, G.
Wasserwirt.-Wassertech. (Berlin), 4: 191, 1954. Water Pollut. Abstr., 29: 28(166), 1956.

Descriptors: Sludge disposal, Sprinkler irrigation, Forage crops, Memmingen, Germany.

The author describes the sewage works of Memmingen where sewage, after sedimentation for 1.5 hours, is used as artificial rain. The yield of hay on watered land has been increased by 52 percent.

087 I SPRAY IRRIGATION FOR POULTRY AND CANNING WASTES
Bell, James W.
Pub. Works, 86: 111-112, September 1955.

Descriptors: Sprinkler irrigation, Wastewater disposal, Food processing wastes, Arkansas, Rates of application.

Liquid waste disposal from two poultry-processing plants and a canning plant in Arkansas is described. In each case, septic tank failure and/or lagooning resulted in objectionable conditions. Plant wastes are screened and applied to the soil directly or by spraying. Rates of application vary from 10 to 60 inches per year, and 0.25 to 0.7 inches per day for short periods. Spray irrigation is considered a water conservation method. The three plants consider this method of disposal to be satisfactory and suitable where municipal disposal facilities are not available. Some monetary return is realized from the irrigated land.

088 I DISPOSAL OF CANNERY WASTES BY IRRIGATION
Brown, H. D., H. H. Hale, and W. D. Sheets
Food Packer, 36: (8)28-32 & (9)30, 32 and 41, 1955.

Descriptors: Flood irrigation, Furrow irrigation, Sprinkler irrigation, Costs, Soil types.

Four methods of irrigation now used are furrow, ditch, flood, and spray. The soil type and land contour determine the appropriate method to use. Stagnant water must be avoided. Vegetation assists in water disposal by transpiration and soil conditioning. Details are given on spray irrigation field tests. Costs are considered. Information is given on the best type of spray nozzle.

089 I STUDIES OF WASTE WATER RECLAMATION AND UTILIZATION
Bush, A. F., and S. F. Mulford
Calif. State Water Pollut. Contr. Board, Sacramento, Publ. No. 9, 1954. 82 p.

Descriptors: California, Groundwater recharge, Groundwater contamination, Soil types, Odor.

This report covers the determination of (a) relationship of underground water pollution to methods and rates of spreading and percolation rates of reclaimed waste waters; (b) the effects on underground water pollution of increasing the percolation rates of reclaimed waste waters by means of cropping and vegetation, additives to top layers of soil, forced irrigation, or other means; (c) degree of contamination and/or pollution of a variety of truck crops on maturity, where the reclaimed waste waters: from various sources, including sewage and industrial wastes, have been applied to the crops and spreading areas by flooding, spraying, or other means; and (d) the extent of odor and other nuisances which may result from this procedure.

It is recommended that waste water be considered a water resource and that further studies be made of percolation rates and degree of treatment required to handle the pollution load, also to remove salts (sodium and boron) from sewage and industrial waste.

Useful references and a bibliography are included.

090 M UNDERGROUND MOVEMENT OF BACTERIAL AND CHEMICAL POLLUTANTS
Butler, R. G., G. T. Orlob, and P. H. McGauhey
J. Amer. Water Works Ass., 46: 97-111, February 1954.

Descriptors: Groundwater movement, Groundwater contamination, California, Water quality standards, Deep percolation.

The movement of bacterial and chemical pollutants via water-percolating through the soil above the water table has been studied somewhat more extensively than the travel of pollution via groundwater movement. Emphasizes the need for investigations in both areas. From reports in the literature and the results of field and pilot-scale studies conducted by the University of California Sanitary Engineering Research Laboratories (SERL), several significant conclusions were drawn. These are listed and briefly discussed. A bibliography with 29 entries is included.

091 I SOME PROBLEMS ENCOUNTERED IN SPRAY IRRIGATION OF CANNING PLANT WASTES
Canham, Robert A.
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 120-134.

Descriptors: Sprinkler irrigation, Wastewater treatment, Costs, Organic loading, Food processing wastes.

Seasonal operation requires that waste treatment systems have relatively low capital investment and reasonable operating cost. The organic loading may vary widely with different types of canning wastes. Other waste characteristics are discussed.

Considers the problems encountered in spray irrigation, such as availability of land, soil type, ground slope, frequency of application, cover crops, and spray distribution systems.

092 I SPRAY IRRIGATION OF FOOD PROCESSING WASTES
Dennis, Joseph M.
Sewage Ind. Wastes, 25: 591-595, May 1953.

Descriptors: Food processing wastes, Spray disposal, Costs.

Many food-processing plants are located in small towns where treatment plant facilities are not adequate to accommodate both industrial waste and domestic sewage. To discharge the wastes into small streams creates serious nuisance and pollution problems, especially in periods of low streamflow or dry periods. Disposal by spray irrigation has solved the problem for many processing plants. Examples are cited, and costs are discussed. The method must be adapted to the individual situation. The need for more research is recognized.

093 I DISPOSAL OF LIQUID WASTES BY THE IRRIGATION METHOD AT VEGETABLE CANNING PLANTS IN MINNESOTA 1948-1950

Drake, J. A., and F. K. Bieri
In: Proc. 6th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1951. p. 70-79.

Descriptors: Minnesota, Food processing wastes, Design data, Furrow irrigation, Odor.

Minnesota had 31 vegetable canneries in 1950 that operated from June to mid-September. Six plants that use spray irrigation or ridge and furrow are described. In the four spray irrigation systems, application rates ranged from 0.25 to 0.5 inches per day on predominantly clay soils. For the two ridge and furrow systems, application rates ranged from 0.55 inches per day on clay loam to 2.15 inches per day on sandy loam. Odors were encountered when irrigating with lagooned wastes but no odors were noticed when irrigating with fresh wastes.

094 M SALMONELLA IN IRRIGATION WATER

Dunlop, S. G., R. M. Twedt, and W. L. Wang
Sewage Ind. Wastes, 23: 1118-1122, September 1951.

Descriptors: Primary effluent, Pathogenic bacteria, Furrow irrigation, Vegetation damage.

Salmonella were recovered from a significant proportion of samples of irrigation water contaminated with a primary-treated sewage plant effluent. These same organisms, however, were not recovered from samples of vegetables irrigated with this water. Furrow irrigation was the method of application. Any organisms in the water would have to be splashed onto the leaves and stems above the ground or conveyed to the plant by some other means. Root crops might be expected to be contaminated to a greater extent.

095 M QUANTITATIVE ESTIMATION OF SALMONELLA IN IRRIGATION WATER

Dunlop, S. G., R. M. Twedt, and W. L. Wang
Sewage Ind. Wastes, 24: 1015-1020, August 1952.

Descriptors: Pathogenic bacteria, Coliforms, Vegetable crops, Human diseases.

A quantitative method was developed for estimating *Salmonella* numbers in sewage-contaminated irrigation water. Of 11 such samples, 8 were positive for *Salmonella*. The median value for the 11 samples was 0.9 per 100 ml. Only 1 to 14 samples of vegetables irrigated with this water was positive for these organisms. Ratios of 225,000 coliforms and 4,800 enterococci to one *Salmonella* were computed from the median values obtained from the water samples.

096 M THE IRRIGATION OF TRUCK CROPS WITH SEWAGE CONTAMINATED WATER

Dunlop, Stuart G.
Sanitarian, 15: 107-110, 1952.

Descriptors: Wastewater treatment, Fruit crops, Pathogenic bacteria, Vegetable crops.

Evidence is presented that a significant proportion of irrigation water samples, contaminated with treated and untreated sewage effluents, contain pathogenic enteric microorganisms. Such organisms, however, were only rarely isolated from the washings of vegetables irrigated with this water. The author points out that it would therefore appear that the health hazard associated with the use of sewage-contaminated water for the irrigation of truck crops to be consumed raw is not as great as has been assumed in the past; nevertheless, the fact that the water has been demonstrated to be contaminated indicates that a hazard still exists, and that every effort must be made to provide adequate treatment of all domestic and industrial wastes before discharging into streams to be used later for irrigation purposes.

097 I CANNERY WASTE DISPOSAL BY IRRIGATION

Dunstan, G., and J. Lunsford
Sewage Ind. Wastes, 27: 827-834, July 1955.

Descriptors: Food processing wastes, Sprinkler irrigation, Washington, Forage crops, Organic loading.

This study was conducted to determine the feasibility of disposal of cannery waste by irrigation. The wastes were from the Green Giant Company, Dayton, Washington, which cans asparagus and peas. Two types of cover crop were tested. One was alfalfa and the other was pasture grass. For the purpose of comparison, both blancher wastes and plant effluent were used, and three types of watering procedures were tried.

The study showed that the organic loading of blancher waste killed the plants. The effect was similar to that of an over-application of fertilizer. On the plots irrigated with effluent, the hydraulic loading (4 in./day) seemed to be the controlling factor. The application of undiluted blancher waste to these types of plants is impractical, due to the fact that the foliage would be burned unless only one or two applications were made.

The data also point up the fact that the permanent pasture grasses were apparently able to take a heavier organic loading than alfalfa under identical conditions.

098 S REGULATIONS FOR IRRIGATION AND THE USE OF SEWAGE SLUDGE

Falkenhain, H. S.

Wasserwirt.-Wassertech. (Berlin), 3: 293-294, 1953. Water Pollut. Abstr., 28: 273(1805), 1955.

Descriptors: Wastewater treatment, Human diseases, Sludge disposal, Pathogenic bacteria, Germany.

Proposed German regulations for irrigation and for the use of sewage sludge are discussed. The author considers the divergent views in the literature on the subject of preliminary treatment of sewage and trade waste waters for use in agriculture. Special importance attaches to the destruction of parasitic worms and pathogenic bacteria. During sedimentation the numbers of these are reduced, but the danger of infection is not removed.

099 M CHEMICAL CHANGES IN SEWAGE DURING RECLAMATION BY SPREADING

Greenberg, A. E., and P. H. McGauhey

Soil Sci., 79: 33-39, January 1954.

Descriptors: Wastewater treatment, Spreading basins, Water quality data, Deep percolation, California.

In arid and semi-arid regions, treated sewage is spread on the ground and the water percolates down to the groundwater. Results of chemical analyses of percolating liquids in four spreading basins in California are tabulated. Samples were collected and analyzed to a depth of 13 feet. Concentrations of Ca, Mg, Na, and Cl ions remained the same. K decreased by 50 percent. Ammonia and P were completely removed within the first 4 feet. Sulphates and bicarbonates increased by 30 percent and nitrate by about 200 percent. Nitrification accounts for the increase in nitrate. It is suggested that these changes are due to biological activity in the soil.

100 I SEWAGE EFFLUENT RECLAMATION FOR INDUSTRIAL AND AGRICULTURAL USE

Greenberg, Arnold E., and Jerome F. Thomas
Sewage Ind. Wastes, 26: 761-770, June 1954.

Descriptors: California, Water quality standards, Groundwater contamination, Groundwater recharge, Spreading basins.

Planned reclamation is designed to produce a usable water from sewage. Such reclaimed waters may be used by industry or agriculture "directly" or "indirectly." The latter involves replenishing groundwater basins from which industrial, agricultural, or domestic supplies are drawn.

Experiments performed by the University of California's Sanitary Engineering Research Laboratory are discussed, and the conclusions are summarized:

1. *A bacteriologically safe water can be produced from settled or more highly treated sewage if the liquid passes through at least four feet of soil.*
2. *A water of chemical quality satisfactory for most uses can be produced from settled sewage or final effluents, provided high concentrations of undesirable wastes are not included in the raw sewage.*
3. *To obtain relatively high rates of percolation, a highly treated sewage plant effluent must be used for spreading.*
4. *A percolation rate of 0.5 acre-ft. per acre per day, can be expected when spreading final effluent on Hanford fine sandy loam.*

5. *The optimum method of operation is to spread continuously for a month, preferably with liquid containing large amounts of organic matter, then to allow the basin to rest until it is air dried. Thereafter, cultivation of the dry soil is desirable. Following this preliminary treatment, continuous application of a final effluent may be carried on for as long as six months. Resting and cultivation may then be repeated.*

6. *Mosquitoes in spreading basins will create a nuisance and health hazard unless control measures are adopted. If algal odors are pronounced, the control of algae also may be necessary.*

7. *Further investigation is needed of sewage percolation in different soils and of phenomena associated with the movement of water into such soils to generalize the conclusions reached as a result of this study with Hanford fine sandy loam.*

101 M FINAL REPORT ON FIELD INVESTIGATION AND RESEARCH ON WASTE WATER RECLAMATION AND UTILIZATION IN RELATION TO UNDERGROUND WATER POLLUTION

Gotaas, Harold B., et al

Calif. State Water Pollut. Contr. Board, Sacramento, Publ. No. 6, 1953. 124 p. Abstr., Sewage Ind. Wastes, 26: 927-928, July 1954.

Descriptors: Spreading basins, Deep percolation, Groundwater contamination, Soil types, California.

Circular spreading basins, 19 feet in diameter, were constructed and equipped so that samples of the percolating liquid could be collected at various depths for bacteriological and chemical analyses. Spreading was studied with three liquids: fresh water; sewage treatment plant final effluent having a BOD of about 10 ppm; and settled sewage with a BOD of about 100 ppm. A number of operating variables were studies to determine the conditions which gave maximum percolation rates and minimum contamination or pollution of the groundwater. These included (1) nature of liquid, (2) length of spreading period, (3) length of resting period, and (4) effect of surface treatment such as spading, sand cover, and application of soil stabilizer.

Some of the conclusions were:

1. *A bacteriologically safe water can be produced from settled sewage or final effluent if it passes through at least 4 feet of soil.*
2. *A water of satisfactory chemical quality can be produced providing high concentrations of undesirable industrial wastes are not included in the raw sewage.*
3. *A highly treated sewage effluent must be used to obtain high rates of percolation.*
4. *A percolation rate of 0.5 acre-ft per acre per day can be expected when spreading a final effluent on Hanford fine sandy loam.*
5. *The optimum method of operation is to spread continuously for about a month, allow the basin to rest until moisture content approaches permanent wilting point, then cultivate the dry soil. Continuous application of effluent may then be carried on for as long as 6 months. Resting and cultivation may then be repeated.*
6. *Mosquito control will be necessary, and algae control may be required.*
7. *Study was conducted on Hanford fine sandy loam. Further investigations would be necessary to generalize the findings to include other soil types.*

102 S THE PROBLEM OF AGRICULTURAL UTILIZATION OF SEWAGE
Grubinger, H.
Bodenkultur (Vienna), 7: 279-291, 1953. Abstr., Soils Fert., 18: 64(327), 1955.

Descriptors: Sprinkler irrigation, Forage crops, Recycling nutrients.

The author discusses the technical features of the purification of sewage and sprinkler irrigation with sewage. Irrigation with 1500-3000 cu.m. per hectare of purified sewage annually supplies 120-240 kg/ha N; 30-60 kg/ha P_2O_5; and 52-104 kg/ha K_2O. Irrigation with such waters and application of the sludge are particularly suited for nitrogen fertilizing, especially of grassland.

103 I FUNDAMENTALS OF THE CONTROL AND TREATMENT OF DAIRY WASTE
Harding, H. G., and H. A. Trebler
Sewage Ind. Wastes, 27: 1369-1382, December 1955.

Descriptors: Dairy wastes, Rates of application, Sprinkler irrigation, Organic loading, New York.

Disposal rates as high as 134,000 gallons per acre per day are reported from studies done in Iowa by ridge and furrow irrigation. Freezing is reported not to hinder this method. Volume and not BOD is the controlling factor for land disposal. Spray irrigation is reported to be of interest, especially in wooded areas where high organic loadings may be handled.

104 S DISPOSAL OF WET DIGESTED SLUDGE AT MARSHALL, MISSOURI
Hayob, Henry
Sewage Ind. Wastes, 26: 93-95, January 1954.

Descriptors: Missouri, Sludge disposal, Soil types, Anaerobic digestion.

Sludge drying beds were eliminated, and liquid sludge is now hauled by tank truck to be spread directly onto farming land. No mention is made of crops grown, soil type, or crop yields. Several problems were solved with this new type of disposal.

105 I SEWAGE EFFLUENT DISPOSAL THROUGH CROP IRRIGATION
Henry, C. D., R. E. Moldenhauer, L. E. Engelbert, and E. Truog
Sewage Ind. Wastes, 26: 123-133, February 1954.

Descriptors: Wastewater treatment, Wisconsin, Oxidation lagoons, Coliforms, Denitrification.

The use of sewage effluent for irrigation is well known in the arid parts of the U.S. It is practical in the other parts of the country, including the northern parts, where the wastewater can be stored in lagoons during the winter. This test in Madison, Wisconsin, applied more than 50 inches of water per season, producing substantial increases in crop yields. Nitrogen, potassium and phosphorus were almost totally removed from the effluent, as were coliforms.

106 S FIFTEEN YEARS OF THE UTHLEBEN SEWAGE COOPERATIVE
Holler, K.
Wasserwirt.-Wassertech. (Berlin), 2: 397, 1952. Abstr., Sewage Ind. Wastes, 26: 118, January 1954.

Descriptors: Sprinkler irrigation, Grain crops, Raw sewage, Wastewater disposal.

Progress and effect of 15 years of sewage farming and technical installations are described. Of about 613 hectares (1,515 acres) 440 hectares received spray irrigation and 173 hectares received trench irrigation. The present maximum sewage flow is about 4,800 cu. m. per day (1.27 mgd). The raw sewage flows through a grit removal unit and thence into a 5,000 cu. m. equalizing lagoon functioning at the same time as a settling basin. This is drained once a year for sludge removal. About 50 percent of the wet sludge is used directly with cattle manure on the fields. The other 50 percent is dried on beds and composted with garbage. The sewage is pumped to the land through movable pipes. The importance of proper timing of irrigation is emphasized and illustrated for grains (oats, wheat), beets, rape seed, and pastures. Comparisons of crop yields with non-irrigated surrounding areas are given.

107 M SUPPLEMENTAL IRRIGATION WITH TREATED SEWAGE
Hunt, Henry J.
Sewage Ind. Wastes, 26: 250-260, March 1954.

Descriptors: Sprinkler irrigation, Soil types, Climatic data, Wastewater disposal, Reviews.

The history of sewage irrigation from the 19th Century to the present is reviewed. The factors affecting supplemental irrigation are discussed. These are water requirements, area required, best crops, methods of application, increased yields, and time and amount of irrigation. Factors influencing the amount of irrigation are soil type, kind of crop, and local weather conditions. Lengthy periods of soil saturation must be avoided, since it is required that soil air enter the root zone. Climate data are shown for several U.S. stations.

108 M AGRICULTURAL UTILIZATION OF SEWAGE
Ippolito, G.
Ing. Sanit. (Milan, Italy), 1: 15-20, 1955. Water Pollut. Abstr., 29: 202(1107), 1956.

Descriptors: Wastewater treatment, Wastewater disposal, Water reuse, Oxidation lagoons, Recycling nutrients.

The author advocates broad irrigation with emphasis on the utilization of sewage for the growing of crops rather than as a method of sewage disposal. Before installation, studies of crop selection and rotation must be made in order to fully utilize the sewage. Sewage treatment plants will be necessary at most locations to provide acceptable sewage disposal for those periods when crop raising is not practicable. Plain sedimentation is recommended for the sewage prior to its use for irrigation to reduce the quantity of organic matter in the irrigation water; the utilization of the resulting sludge as fertilizer elsewhere is recommended.

109 M THE AVAILABILITY OF NITRATES IN SEWAGE EFFLUENTS
Jepson, C.
J. Inst. Sewage Purif. (London), p. 148, 1951. Abstr., Sewage Ind. Wastes, 27: 355, March 1955.

Descriptors: Nitrate contamination, Water quality data, Surveys, Nitrification, England.

Although oxidized nitrogen is a potential source of oxygen, the latter does not become available for biological life until all the free dissolved oxygen has disappeared. Presence of nitrate in an effluent can delay or prevent the onset of putrescence. Given an adequate retention period during which any dissolved oxygen is exhausted, settled sewage may be improved in quality by the reduction of oxidized nitrogen. To obtain a correct estimate of oxidized nitrogen, analysis should be made as soon as possible after sampling or special precautions taken to retard biological activity.

110 M SOME ASPECTS OF IRRIGATING GRASSLAND IN HUMID REGIONS AND THE USE OF SEWAGE
Julen, G.
In: Proc. 6th Int. Grassland Cong., Penn State Univ., State College, Pa., 1952. Vol. I, p. 394-396. Abstr., Soils Fert., 18: 450(2303), 1955.

Descriptors: Forage crops, Nutrient removal, Wastewater disposal, Plant growth.

Higher grass production can be obtained by irrigating during periods of drought when insolation is greater than by high rainfall associated with poor light conditions. Sewage waters are useful, though their high N content may depress legumes in leys.

111 M TREATMENT OF SEWAGE PLANT EFFLUENT FOR INDUSTRIAL RE-USE
Keating, R. J., and V. J. Calise
Sewage Ind. Wastes, 27: 773-782, July 1955.

Descriptors: Wastewater treatment, Water reuse, Design data, Wastewater disposal, New York.

One practical and substantial source for additional industrial water supplies is the effluent from municipal sewage treatment plants. The author discusses current developments and factors involved in the design of equipment for treatment of sewage plant effluents for reuse in industrial processes and boiler feed applications.

112 M PUBLIC HEALTH ASPECTS OF SEWAGE FARMING
Koziorowski, Bohdan
Gaz Woda Tech. Sanit. (Warsaw), 27: 100. Abstr., Sewage Ind. Wastes, 25: 1480, December 1953.

Descriptors: Primary effluent, Human diseases, Recycling nutrients, Sprinkler irrigation.

Secondary treatment of the sewage should precede its use in sewage farming, but this is costly and fertilizer value is reduced by 20 percent over that of primary treatment. The spraying of primary effluent on fields and forests is recommended, but produce taken from these fields should be processed properly before consumption.

113 S HYGIENIC EVALUATION OF THE AGRICULTURAL UTILIZATION OF SEWAGE
Kruez, C. A.
Gesundh. Ing. (Munich), 76: 206-211, 1955.

Descriptors: Public health regulations, England, United States, Germany, Soviet Union.

The author discusses the hygienic problems arising from the agricultural utilization of sewage and the amount of agricultural use in the United States, Great Britain, the Soviet Union, and Germany. He considers the dangers to health, precautions necessary in the use of sewage and sludge, the fertilizer and humus-forming effects of sewage and sludge, and the effect of treatment on the fertilizing constituents.

114 I DISPOSAL OF LIQUID AND SOLID WASTES BY MEANS OF SPRAY IRRIGATION IN THE CANNING AND DAIRY INDUSTRIES

Lane, L. C.
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 508-513.

Descriptors: Food processing wastes, Iowa, Water quality data, Dairy wastes, Spray disposal.

The author reviews several operations that used spray irrigation for the disposal of cannery and dairy wastewater and summarizes the components of which a typical spray system might consist. He sums up the merits of spray irrigation as the following: (1) stream pollution has been controlled successfully with the spray application; (2) odor control has been accomplished at each installation; (3) BOD has not been a great concern to the design of the system; (4) the system is simple to operate and can be fully automatic; (5) land is not held in an unproductive state as in the case of lagoons; (6) the equipment can be used for regular irrigation service by canneries before the canning season begins; and (7) the costs are relatively low.

115 M POLLUTION CONTROL OF THE RIO GRANDE IN NEW MEXICO

Lowe, Robert P.
Sewage Ind. Wastes, 24: 1021-1024, August 1952.

Descriptors: New Mexico, Planning, Water reuse, Wastewater treatment, Water management (applied).

Irrigation of agricultural crops is by far the major use of water on the Pecos and Rio Grande rivers in New Mexico. Water shortages have limited industrial development that must depend on adequate water supply. The demand for use of all available water in New Mexico, Texas, and the Republic of Mexico necessitates close control of pollution so that the maximum usage of water may be obtained. This need has been reflected in New Mexico through constant demands for use of sewage effluents for irrigation. Growth is expected to continue, increasing the need for domestic sewage and industrial waste treatment facilities. Only continued and alert control can prevent extensive problems from being created.

116 M SEWAGE RECLAMATION AT GOLDEN GATE PARK
Martin, B.
Sewage Ind. Wastes, 23: 319-320, March 1951.

Descriptors: Costs, San Francisco, California, Suspended solids, Tertiary treatment, Recreational facilities.

The author describes the sewage treatment system at Golden Gate Park and the irrigation of the park by the plant effluent. The characteristics of the sewage incoming to the plant are 250 ppm suspended solids and 350 ppm BOD. After primary treatment the settled sewage has a suspended solids content of 50 ppm and a BOD of 150 ppm. After secondary treatment, both the BOD and the suspended solids are less than 5 ppm in samples taken from the final settling tank. Chlorination is carefully controlled and a residual of 2 ppm after the full contact period is maintained. The plant effluent meets drinking water standards.

The cost per 1,000 gal. of effluent at the plant is $0.07. Gravity flow is sufficient to maintain those lakes which are at a lower elevation. For irrigation purposes, and for maintaining the level of Stow Lake, where a boating concession has been established, effluent must be pumped from the plant reservoir. The cost of pumping is $0.04 per 1,000 gal. These costs compare with a cost of $0.22 per 1,000 gal. for irrigation water taken from the distribution system of the domestic supply (cost data were taken from a survey based upon the 1948-1949 water production and included in the annual operating cost was the total of certain capital improvements made during that fiscal year).

117 I THE DISPOSAL OF INDUSTRIAL EFFLUENT BY WOODS IRRIGATION
Mather, J. R.
In: Proc. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1953.
p. 439-454.

Descriptors: Food processing wastes, Rates of application, Clogging (soil), Groundwater recharge, Seabrook Farms, New Jersey.

Seabrook Farms Company disposes of cannery waste effluent by means of woods irrigation. The spreading of 400 to 600 inches of wastewater onto forest soil during an eight-month period, while causing a rise in the water table did not seriously clog the soil, or result in swamps or a completely saturated soil. In fact, as a result of the vegetational changes accompanying the spraying operation, the disposal area appeared to be better covered the second and third years than before operations began. Recovery of the *groundwater table to predisposal operation level was nearly complete during the four-month winter period. The vegetation and soil of the disposal area act as a most efficient filter for, on the basis of well analyses, it was found that no pollution of the groundwater had occurred as a result of the spraying.*

118 I SPRAY IRRIGATION OF DAIRY WASTES
McKee, F.
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 514-518.

Descriptors: Organic loading, Design data, Dairy wastes, Sprinkler irrigation, United States.

Six spray irrigation installations for the Kraft Foods Company are described. The wastes are milk and whey. Loading rates vary from 0.6 to 1.6 in./wk. Operating data on the six plants located at Berwick, Ontario; Alexandria, Tennessee; Owenton, Kentucky; Shirley, Indiana; Paoli, Indiana; and Milan, Wisconsin, are given. Two of the plants have been replaced with conventional treatment systems.

119 M A SURVEY OF DIRECT UTILIZATION OF WASTE WATERS
Merz, Robert C.
Calif. State Water Pollut. Contr. Board, Sacramento, Publ. No. 12, 1955. 80 p.

Descriptors: Groundwater recharge, Recreational facilities, Wastewater disposal, California, Surveys, Bibliographies.

A comprehensive survey of current practices in the use of wastewater by industry, by agriculture, for recreation, and for groundwater recharge. The study permitted the following conclusions with regard to the agricultural use of wastewater: (a) Sewage effluent has been shown to be a satisfactory irrigation water, where chemical concentrations permit and where health regulations pertaining to type of crop are met; (b) Sewage effluent has been shown to be an adequate medium for leaching alkali soils, or improvement of barren soils; (c) Reclamation by land irrigation is a means of protecting the quality of surface waters; (d) Irrigation provides secondary treatment and disposal of wastes in an economical manner and may provide the municipality with a substantial monetary return; and (e) An ideal use of oxidized sewage effluent is for irrigation of parks and golf courses and as a supply for decorative lakes. Conclusions pertaining to other uses are also given.

Numerous examples of reuse are cited, and pertinent abstracts from the literature are included. The bibliography contains 227 entries.

120 I SPRAY IRRIGATION AT MORGAN PACKING COMPANY
Miller, P. E.
In: Proc. 8th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1953. p. 284-287.

Descriptors: Food processing wastes, Spray disposal, Rates of application, Odor, Indiana.

The Morgan Packing Company of Austin in southeastern Indiana processes beans, soups, hominy, beets, and tomatoes. A flow of 1.3 mgd is sprayed on 240 acres for a loading rate of 5,400 gad. The wastewater passes through 3/8 inch screens, into a 2-hour equalizing reservoir before being sprayed. The portable sprinkling system applies 0.44 in./hr with equal resting and sprinkling times. There were no insect or odor problems and the Kentucky fescue in the spray area grew twice as high as in non-sprayed areas.

121 M ABWASSERRIESELUNG IN AUSTRALIEN
(IRRIGATION WITH SEWAGE IN AUSTRALIA)
Mueller, W.
Wasser Boden (Hamburg), 7: 12-14, 1955.

Descriptors: Melbourne, Australia, Rates of application, Fruit crops, Wastewater disposal, Forage crops.

The author gives an account of the conditions under which sewage is used for irrigation in Australia. Only settled and biologically treated sewage may be used. Surface irrigation is preferred. The amounts vary from 350 to 7500 mm. per year. Land for arable and pasture use and for fruit growing is irrigated.

122 I CANNERY WASTES DISPOSAL BY SPRAY IRRIGATION
Nelson, Leonard E.
Wastes Eng., 23: 398-400, 1952.

Descriptors: Odor, Minnesota, Sprinkler irrigation, Costs, Food processing wastes.

In 1951, an installation in Minnesota used 24 million gallons of cannery wastewaters to irrigate 110 acres of crops. Crop yields were increased, and no nuisance odors resulted. Portable aluminum pipe was used for sprinkler lines. The pipe was moved as required to control distribution of water to the crops. Cost data are given for the installation.

123 M STREAM POLLUTION - BACTERIOLOGICAL STUDY OF IRRIGATED VEGETABLES

Norman, N., and W. Kabler
Sewage Ind. Wastes, 25: 605-609, May 1953.

Descriptors: Pathogenic bacteria, Coliforms, Vegetable crops, Sprinkler irrigation.

The coliform content of the irrigated soils studied reflects, in general, the coliform density of the waters they receive. Vegetables irrigated with waters of high coliform count exhibit a higher coliform flora than vegetables irrigated with relatively pure water. The coliform density of leafy vegetables irrigated with polluted water is higher than that of smooth vegetables grown under similar conditions. Under the conditions of this study, the enterococcus indices of soils and vegetables showed no direct relationship to the indices of irrigation waters. Salmonella were present in the irrigation waters in readily demonstrable numbers, were present in soils in only low concentrations, and were insufficiently numerous on the vegetables to be demonstrated by the procedures used.

124 M AN INVESTIGATION OF SEWAGE SPREADING ON FIVE CALIFORNIA SOILS

Orlob, G. T., and R. G. Butler
University of California, Berkeley, SERL Tech. Bull. 12, June 1955. 53 p.

Descriptors: Spreading basins, Soil types, Groundwater recharge, Aerobic conditions, Water quality data, California.

The infiltration rate for each soil was found to follow the same general pattern: (1) an abrupt decrease in rate attributed to dispersion of soil particles; (2) an increase in rate due to solution of entrapped gases into the percolating liquid; and (3) a decrease due to accumulation of biological slimes in the soil voids. Infiltration rates in the third phase ranged from 30 feet per day for the most permeable soil to 0.6 feet per day for the fine soils.

Infiltration of settled sewage applied to soil lysimeters decreased sharply due to clogging of soil surface by particulate matter. Coliform removals were generally highest in the fine soils. Increases in calcium and magnesium concentrations and decreases in sodium and potassium concentrations in the percolates were observed.

Aerobic conditions existed for the first few weeks of sewage spreading after which anaerobic conditions persisted. Increases in BOD in the effluents from the soils were obtained after the anaerobic stage predominated. Organic matter penetrated the surface strata of the lysimeter soils, causing decreases in permeability and infiltration rates. Abrupt loss in hydraulic head through surface strata was experienced for all soils receiving the sewage application.

Particle-size characteristics of the five soils studied could not be correlated with the observed infiltration rates. Therefore, field performance of a soil cannot be predicted by comparing its particle-size characteristics with those of other soils for which infiltration rates have been established.

125 M J ERFAHRUNGEN AUF DEM GEBIET DER LANDWIRTSCHAFTLICHEN ABWASSERVERWERTUNG
(EXPERIENCES IN THE AGRICULTURAL UTILIZATION OF SEWAGE)
Paulsmeier, F.
Desinfekt. Gesundheitsw. (Hannover, Ger.), 47: 118-122, 1955.

Descriptors: Recycling nutrients, Sprinkler irrigation, Economic feasibility, Wastewater disposal, Berlin, Germany.

From experience with the irrigation fields of Berlin, the author discusses the agricultural and economic advantages of agricultural use of sewage. He gives figures for the amounts of nutrient substances in the sewage of Germany and deals with arguments raised against agricultural utilization.

126 I BROAD FIELD DISPOSAL OF BEET SUGAR WASTES
Porges, Ralph, and Glen J. Hopkins
Sewage Ind. Wastes, 27: 1160-1170, October 1955.

Descriptors: Food processing wastes, Nebraska, Water quality data, Rates of application, Flood irrigation.

The Great Western Sugar Company in Bayard, Nebraska used field disposal for its industrial wastes. Results were very favorable; BOD was reduced from 483 ppm to 158 ppm; bacteriological reduction was about 75-89 percent, and SS removal was over 99 percent. The wastes were allowed to run over a field of 160 acres, about 3,500 feet long. Waste flow is given as 4.3 cubic feet per minute.

127 M CALIFORNIA REGULATES USE OF SEWAGE FOR CROP IRRIGATION
Reinke, E. A.
Wastes Eng., 22: 364, 376, 1951.

Descriptors: Public health regulations, California, Raw sewage, Fruit crops, Water quality standards.

The State Department of Public Health has adopted regulations governing use of sewage for crop irrigation. They prohibit use of raw sewage on growing crops; provide that partially disinfected effluents shall not be used to water growing vegetables, garden truck, berries, or low-growing fruits such that fruit is in contact with the ground; but may be used on nursery stock, cotton, and such field crops as hay, grain, rice, alfalfa, sugar beets, fodder corn, cowbeets, and fodder carrots. Well-oxidized nonputrescible and reliably disinfected or filtered effluents, which meet the bacterial standards established for drinking waters, may be used without restriction. The degree of sewage pollution of irrigation waters varies with the source of supply.

128 M LAND TREATMENT OF SEWAGE
Reploh, H.
Kommunalwirtschaft (Germany), 8: 401, 1955. Water Pollut. Abstr., 29: 352(1932), 1956.

Descriptors: Sprinkler irrigation, Odor, Human diseases. Groundwater recharge.

The author discusses the advantages of agricultural utilization of sewage, methods of preventing odor nuisance and spreading of bacteria, and the importance of this method of disposal to the groundwater supply.

129 M EFFLUENT FOR IRRIGATION
Rockwell, F. L.
Amer. City, 69: 92, September 1954.

Descriptors: Texas, Sludge disposal, Oxidation lagoons, Flood irrigation, Grain crops.

Brownsville, Texas has a new plant for sewage treatment consisting of primary sedimentation tanks, percolating filters, and final sedimentation tanks. Sludge is digested and dried on open beds. Owing to the shortage of water for irrigation, farmers have been allowed to divert the effluent being discharged to the Rio Grande to irrigate crops of cotton and corn.

130 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL
Rudolfs, Willem, Lloyd L. Falk, Robert A. Ragotzkie
Sewage Ind. Wastes, 23: 253-258, March 1951.

Descriptors: Coliforms, Furrow irrigation, Pathogenic bacteria, Human diseases.

Field experiments during two growing seasons were designed to evaluate and compare the extent of coliform contamination of tomatoes to those grown in a similar but uncontaminated environment. The pollution consisted of either furrow irrigation with settled sewages normally used for the purpose, or direct application of feces suspensions to the fruit and leaves, which may represent spray types of irrigation on direct application of night soil as frequently practiced. In addition, the survival of pathogenic types, such as Salmonella and Shigella genera, was investigated to supplement with direct evidence the findings with coliform organisms. The results show that if sewage irrigation or night soil application is stopped one month before harvest, the fruit, if eaten raw, would not likely be vectors for the transmission of human bacterial enteric diseases.

131 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL: II. FIELD AND LABORATORY STUDIES ON ENDAMOEBA CYSTS
Rudolfs, Willem, Lloyd L. Falk, and Robert A. Ragotzkie
Sewage Ind. Wastes, 23: 478-485, April 1951.

Descriptors: Vegetable crops, Human diseases, Soil physical properties, Flood irrigation.

Laboratory and field experiments on the survival of Endamoeba histolytica cysts applied either in suspension or in conjunction with feces to tomatoes and leaf lettuce direct, or to soil in which the plants were growing, show that the cysts are extremely sensitive to desiccation. Addition of organic matter in the form of fecal suspensions does not enhance survival of the cysts. Crops growing in the field may become contaminated directly during the course of irrigation with sewage polluted water or night soil, or indirectly through contact with polluted soil. Contaminated tomatoes and lettuce are free from viable cysts within three days after contamination occurs, the time of decontamination decreasing with a decrease in the degree of wetness of the soil. Field-grown crops consumed raw and subject to contamination with cysts of E. histolytica are considered safe in the temperate zone one week after contamination has stopped and after two weeks in wetter tropical regions.

132 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL: III. FIELD STUDIES ON ASCARIS EGGS

Rudolfs, Willem, Lloyd L. Falk, and Robert A. Ragotzkie
Sewage Ind. Wastes, 23: 656-660, May 1951.

Descriptors: Coliforms, Detergents, Vegetable crops, Wastewater disposal.

Field experiments on the survival of Ascaris suum eggs were conducted by spraying suspensions of Ascaris eggs and feces on growing tomatoes and lettuce. Plants and fruits were harvested at intervals. Results show that a reduction of the number of eggs took place with time, but some eggs remained on the plants and fruits for more than a month. Development of eggs was greatly retarded and completely developed eggs containing motile embryos required for infection were not recovered. The exposure of undeveloped eggs to field conditions reduced greatly the viability of the eggs. It appears that resistance of Ascaris eggs on vegetable surfaces is less than might be expected from considerations of their resistance in soil, feces, or night soil. All eggs degenerated after 27 to 35 days and were incapable of development for infection.

133 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL: IV. BACTERIAL DECONTAMINATION

Rudolfs, Willem, Lloyd L. Falk, and Robert A. Ragotzkie
Sewage Ind. Wastes, 23: 739-751, June 1951.

Descriptors: Coliforms, Sprinkler irrigation, Human diseases, Vegetable crops.

Studies on coliform decontamination of raw tomatoes grown on sewage polluted soils, or sprayed with E. coli or feces, show that the natural death rate of these bacteria under ordinary storage conditions is slow and does not insure adequate decontamination. Vigorous washing for 15 min. with plain water removes most of the sprayed-on contaminants, but does not remove coliform from tomatoes grown on polluted soil. In general, vigorous washing with anionic, nonionic, and cationic detergents is not materially better than washing with plain water. Chlorine and its compounds in high concentration in solution do not remove organisms protected by dirt, or in cracks, crevices, or bruises. Chlorine gas is a good decontaminating agent, but causes bleaching in the concentrations required. Nitrogen trichloride and t-butyl hypochlorite are not effective in the concentrations normally used for fruit spoilage control. The most effective method for consistently obtaining a low coliform residual, without affecting the appearance and condition of the vegetables, is soaking them in water at a temperature of 60° C for 5 minutes.

134 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL: V. HELMINTHIC DECONTAMINATION
Rudolfs, Willem, Lloyd L. Falk, and Robert A. Ragotzkie
Sewage Ind. Wastes, 23: 853-860, July 1951.

Descriptors: Vegetable crops, Human diseases, Detergents, Clogging (soil).

Physical and chemical means of decontaminating vegetable surfaces contaminated by Ascaris suum eggs included vigorous washing and soaking in plain water, detergent solutions, germicidal rinses, and use of warm water. The results show that the eggs adhere tenaciously to solid surfaces. Various detergents and germicidal rinses were not effective killing agents, but cationic detergents will cause more than 90 percent removal of eggs from smooth surfaces, such as tomatoes. The removal is less effective when cracks, crevices, or bruises protect the eggs. The only effective method to insure vegetable decontamination with respect to helminth eggs is immersion of the vegetable in warm water (55° to 60° C) for 10 minutes.

135 M CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL: VI. APPLICATION OF RESULTS
Rudolfs, Willem, L. Falk, and A. Ragotzkie
Sewage Ind. Wastes, 23: 992-1000, August 1951.

Descriptors: Vegetable crops, Pathogenic bacteria, Human diseases, Coliforms.

The authors state the following general conclusions: No evidence has been found that pollutional bacteria, amoeba, or helminth eggs penetrate healthy, unbroken surfaces of vegetables or cause internal contamination. Vegetables to be eaten raw can be grown without health hazard in soils subjected to sewage irrigation, night soil application, or polluted stream water irrigation in years prior to the season in which the vegetables are grown. Vegetables grown under conditions of surface sewage irrigation show no higher coliform concentrations than those grown on normally farmed soil, whether sewage was applied before the plants were set or while the plants were growing. If sewage sludges or night soil are applied on the soil surface, or sewage effluents are applied by overhead irrigation during growth of vegetables, applications should be stopped at least one month before harvest. If this precaution is taken, the crop will show no higher bacterial contamination than when farmyard manure or artificial fertilizers are applied. Strains of Salmonella and Shigella do not survive on vegetable surfaces for more than one week. Hence, conclusions based upon coliform contamination offer a considerable margin of safety. Bacteria applied to vegetable surfaces are tenaciously held and protected from the external environment. This permits their survival under field conditions and explains the difficulty of their removal by various types of washes or kill by germicides. The resistance of cysts of Endamoeba histolytica to the external environment depends almost entirely on the amount of mositure present. Death of the cysts occurs immediately upon desiccation. During dry periods, cysts of E. histolytica survive less than 3 days on vegetables growing above ground in the field. To reduce to a minimum the danger of transmitting amoebic dysentery through crop contamination, the last application of contaminating material to the soil before harvest should be at least one week in the temperate zone and two weeks in the wetter climates of tropical regions. Eggs of Ascaris suum were recovered in reduced numbers from vegetables one month after application, but all had degenerated, and no completely developed eggs were found on plants in the field. The possible dangers of the transmission of Ascaris are greatly reduced if fecal matter fertilization is stopped one month before harvest. Storage, washing of vegetables in plain water, or washing with various detergents, including anionic, nonionic, and cationic compounds, are ineffective as means of bacteriological decontamination. Germicidal rinses of chlorine and its compounds are superior to water and detergents for bacterial decontamination, but are unreliable. Water, anionic, most nonionic detergents, and chlorinated compounds are not effective decontaminants for helminth eggs; cationic detergents aid in removal of eggs from vegetable surfaces. The eggs are resistant to the killing effects of disinfectants which could be used in vegetable decontamination.

136 I CANNING, FREEZING, AND DEHYDRATION
Sanborn, N. H.
In: Industrial Wastes, Rudolfs, W. (ed.), New York, Reinhold Publishing Corp., 1953. p. 70.

Descriptors: Iowa, Rates of application, Furrow irrigation, Food processing wastes, Costs.

The author describes a field receiving pea and corn wastes in Iowa since 1934. An average flow of 176 gpm is discharged to 1.88 acres by ridge and furrow irrigation. The soil is a "dark" loam and the average loading rate is 5.0 in./day.

Recommended loadings for corn wastes are 1 acre per 100,000-150,000 gpd or 3.7-5.5 in./day. Choose soil that will readily absorb wastes as hydraulic loading is the control rather than solids content of the waste applied. Recommended management is to provide constant attention to direct the flow, allow the furrows to empty before reapplying waste, and permit weeds to grow to utilize transpiration and to reduce wind sweep for odor control.

Total annual operating cost for the Iowa operation (unscreened waste) including the cost of leasing the land was $280 or 0.12 cents per case.

137 I DISPOSAL OF FOOD PROCESSING WASTES BY SPRAY IRRIGATION
Sanborn, N. H.
Sewage Ind. Wastes, 25: 1034-1043, September 1953.

Descriptors: Food processing wastes, Odor, Costs, Sprinkler irrigation.

Spray irrigation has provided a means for the disposal of food-processing wastes which does not pollute streams or create odors. The method can be extended to certain other industrial wastes. Several examples of successful disposal operations are cited.

Disposal systems for typical food-processing plants are described and cost figures given. Certain problems and limitations of spray irrigation systems are discussed.

138 M NEW EXPERIENCES IN AGRICULTURAL UTILIZATION OF SEWAGE

Schwarz, K.
Wasserwirt. Tech. (Berlin), 46: 55, 1955.

Descriptors: Soil types, Subsurface irrigation, Reviews, Germany, Sprinkler irrigation.

The author reviews the papers presented at a meeting of the Deutsche Akademie der Landwirtschaftswissenschaften at Berlin in February 1954. Subject dealt with include: experiments in Neustrelitz on the use of artificial rain on very light soils; the relations between watering, soil, and plant growth in localities of poor soil and the necessity for adequate additional organic manuring; the effect of aritifical rain on the mainly heavy soils of Thuringia; economic problems; subsoil irrigation and its results in Delitzsch, and irrigation fatigue in fields overloaded with sewage.

139 M SUBSOIL IRRIGATION IN THE AGRICULTURAL UTILIZATION OF SEWAGE

Schwarz, K.
Wasserwirt.-Wassertech. (Berlin), 5: 371-373, 1955. Water Pollut. Abstr., 30: 25(148), 1957.

Descriptors: Subsurface irrigation, Soil types, Public health regulations, Germany, Wastewater disposal.

Investigations in the experimental irrigation fields at Greifswald, Delitzsch, and Neustrelitz, on subsoil irrigation, are not sufficient for a final judgment of this method of application of sewage. Further experimental irrigation on fields of medium and heavy soils is recommended. Further investigations on hygiene and the technique of construction and operation of plants are required.

140 M AGRICULTURAL VALUES OF SEWAGE

Skulte P.
Sewage Ind. Wastes, 25: 1297-1303, November 1953.

Descriptors: Planning, Groundwater recharge, Recycling nutrients, Primary effluent, Europe.

Actual experiences have demonstrated that sanitary sewages and many industrial wastes can be successfully used for agricultural, industrial, and other purposes. The sewage as used for irrigation is usually given primary treatment. After that, the processes of natural soil filtration and biochemical stabilization can produce an oxidized and well-treated percolation water. Reclamation programs planned only for groundwater replenishment are usually unsound economic ventures. Therefore, the emphasis should be on the agricultural values in sewage, greatly reducing the immense fertilizer bill and improving soil conditions.

141 M SOME PRINCIPLES OF AGRICULTURAL IRRIGATION
Sisson, Donald R.
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 519-526.

Descriptors: Sprinkler irrigation, Wastewater disposal, Public health regulations, United States.

Irrigation is one of the more important practices designed to minimize the "gamble" in modern agriculture. The benefits of irrigation as practiced in the Midwest are noted. The important factors to be considered in designing an agricultural irrigation system are discussed, as well as some of the problems in the use and management of the system. Some hazards and problems associated with waste disposal, by agricultural irrigation are pointed out.

142 M CONTROL OF FERTILIZING MINERALS IN SEWAGE PLANT EFFLUENTS
Smith, R. L., and W. Subby
Pub. Works, 86: 91-92, February 1955.

Descriptors: Sprinkler irrigation, Anaerobic conditions, Furrow irrigation, Soil chemical properties, Recycling nutrients.

Minerals in sewage-works effluent can cause excessive algae blooms in lakes due to the fertilizing value of the minerals. Methods suggested for solving the problem include diverting the effluent from the lake, with discharge to a flowing stream; disposal on land by furrow or spray irrigation; or removal of algae and thereby removal of fertilizing minerals. The first method was found to be costly and ineffectual as the minerals had already entered the lake. The second method was also *expensive as plants had to be removed before death to prevent return of excess minerals to the soil and, also, because the area of irrigation had to be constantly changed. There was danger of producing high nitrate concentrations in the groundwater in the area. The removal of algae and minerals was found most satisfactory. The algae removed can be used for fertilizer. The lake water was filtered through paper in a metal trough-shaped filter. A description of the filter is given.*

143 M EFFECTS OF SEWAGE ON CATTLE AND GARBAGE ON HOGS
Snyder, W.
Sewage Ind. Wastes, 23: 1235-1242, October 1951.

Descriptors: Human diseases, Pathogenic bacteria, Wastewater treatment, Animal diseases.

In making use of sewage effluents, the degree of treatment required must be governed by its subsequent reuse if the greatest social and economic advantages are to be realized. Since there are many diseases common to both man and animals, the possibility of disease transmission by sewage must not be overlooked. Experiments are cited in which swine were fed with incoming sewage mixed with bran; others were fed with effluent mixed with bran. Careful postmortem examinations revealed no evidence of disease. Cows were supplied with effluent for drinking. Likewise, no evidence of disease was found. It was concluded that virulent bacteria were not present in sufficient concentration in the sludge and effluent of the treatment plant at Beltsville to cause disease in susceptible animals. The feeding of raw garbage to hogs can lead to trichinoisis in the animals and transfer to man if the meat is not properly cooked. Garbage can be cooked to destroy the infection before feeding to the animals.

144 M EFFECT OF SEWAGE IRRIGATION UPON SOILS
Steel, W., and E. J. M. Berg
Sewage Ind. Wastes, 26: 1325-1339, November 1954.

Descriptors: Soil chemical properties, Organic loading, Soil physical properties, Wastewater disposal, Texas.

The relatively small changes in the soils studied indicate that sewage irrigation is neither especially beneficial nor injurious to soils. Sewage irrigation encourages accumulation of chlorides. Leaching of the chlorides was readily accomplished and there should be no injurious accumulations under normal operation. A slight increase in organic matter *(humus) can be expected. Pore space is increased by sewage irrigation, and crumb structure shows some improvement. Sewage-irrigated soils accumulate slightly more phosphorous than water-irrigated soils. Boron also will be contributed to soils by sewage.*

145 I LAND DISPOSAL OF SEWAGE AND INDUSTRIAL WASTES
Stone, Ralph
Sewage Ind. Wastes, 25: 406-418, April 1953.

Descriptors: Water quality standards, Human diseases, Groundwater recharge, Rates of application, California.

The author discusses the disposal of waste effluents by irrigation of restricted crops, or within spreading areas. Soil organisms and filtration provide a "high-quality, fully oxidized, pathogen-free, nonturbid water." Intermittent dosage assures an aerobic environment which is required for nuisance-free disposal. Several examples are cited along with data describing operations. Variable factors important to the design and operation of land disposal facilities are discussed.

Nuisance and health hazards may be controlled through proper design and technical supervision of the operation. Certain highly mineralized industrial wastes may present special problems. Land disposal methods appear to be satisfactory for domestic sewage effluent.

146 M IRRIGATION WITH WASTE WATER
Stone, Ralph
Pub. Works, 86: 97-99, November 1955.

Descriptors: California, Wastewater treatment, Golf courses, Wastewater disposal, Costs.

The author states: "The reuse of sewage and industrial waste waters for irrigation is a means of conserving our available water resources." Not all sewage and industrial wastes in all climates can be safely disposed of by irrigation. In California, 69 localities use waste water for crop irrigation. Beef cattle appear to drink waste water in preference to potable well water. Sewage and industrial waste must be treated regardless of its disposition. Therefore, the cost of treatment should not be charged against the use of water for irrigation. Parks, golf courses, orchards, pastures, cultivated areas, etc., produce more luxuriant crops when irrigated with waste water. Water with a high mineral content is considered unsatisfactory for irrigation. Ponding of waste water from over-irrigation creates nuisance and health hazards and should not be permitted.

147 M SEWAGE TREATMENT IN CALIFORNIA STATE INSTITUTIONS
Stowell, E. R.
Sewage Ind. Wastes, 26: 1347-1354, November 1954.

Descriptors: California, Rates of application, Sprinkler irrigation, Septic tanks, Wastewater treatment.

This article discussed how some sewage treatment problems were solved in the state institutions and other facilities of the State of California. There are many treatment methods which were used for solving sewage problems. One of the methods was the use of hillside sprays for disposal of sewage effluent in recreational areas. Three state parks were selected to install such systems. A standard trickling filter type nozzle is used. This type nozzle has large clearances, thus giving non-clog characteristics and low discharge head requirements. The application rate is not to exceed 2 in./week. The three state parks are Taylor State Park (Marine City), Portola State Park (West of Palo Alto), and Calaveras Big Tree Park (Calaveras City). The pretreating in all cases is by septic tanks.

148 M SEWAGE AND WASTE TREATMENT FOR COAL MINING COMMUNITY, SUNNYSIDE, UTAH
Thackwell, H. L.
Wastes Eng., 26: 352-353, 1955.

Descriptors: Design data, Utah, Aerated lagoon effluents, Wastewater treatment, Sprinkler irrigation.

A new sewage treatment plant has been constructed. It consists of bar screens, aeration tank and grit removal, Imhoff tank, dosing tank, percolating filter, final sedimentation and chlorination tanks, and sludge drying beds. The final effluent is used for irrigation. A flow diagram of the plant is given.

149 S CONSERVATION POTENTIAL OF SEWAGE SLUDGE
Thomson, F., and M. Morgan, Jr.
Water Sewage Works, 102: 532-535, December 1955.

Descriptors: Sludge disposal, Rates of application, Recycling nutrients, Water quality data, United States.

Sewage sludge has been used with varying degrees of success to replace fertility of soils. Sludge contains differing amounts of lime, humus, nitrogen, phosphorus, and potash. Recommended applications are 10 to 60 cu. yd. per acre for flowers, vegetables, and grass and 10 tons of wet sludge per acre for orchards. Average sludge production for the United States is estimated at one million tons per year. Based on analyses from several cities, this would yield 32 thousand tons of nitrogen, 23 thousand tons of phosphate, and 3 thousand tons of potash. There is usually a wide margin between the plant nutrients removed from soil and that which is put back. If all sludge produced in 1949 and 1950 had been used as fertilizer, it probably would have increased production only about 0.5 percent. In spite of this relatively small yield, nothing should be overlooked to increase our agricultural potential.

150 S FERTILIZER VALUE IN WASTE DISPOSAL METHODS
Van Kleeck, W.
Amer. J. Pub. Health, 44: 349-354, March 1954.

Descriptors: Sludge disposal, Recycling nutrients, Connecticut, Sprinkler irrigation, Odor.

Dried or partially dewatered sewage sludge makes an excellent soil conditioner and a good, though incomplete, fertilizer. Heat-dried raw activated sludge is the best sludge product, both chemically and hygienically, although some odor may be encountered in its use. The reasons why more sludge is not used are discussed, as are the advantages and disadvantages of broad irrigation and sewage farming. Garbage composting, both alone and in connection with sewage sludge, is receiving more attention although current practice leaves much to be desired.

151 I LAGOONING AND SPRAY DISPOSAL OF NEUTRAL SULPHITE SEMI-CHEMICAL PULP MILL LIQUORS
Voights, D.
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 497-507.

Descriptors: Michigan, Rates of application, Monitoring, Spray disposal, Pulp and paper wastes.

The experience of the American Box Board Co. at its Filer City, Michigan, plant in reducing its pollutional contribution to Manistee Lake is detailed. The flow of spent liquor was 300,000 gpd in 1951 with a BOD of 20,000-30,000 mg/L. Each 5 acre plot received an average of 10.6 in./day continuously for 3 weeks. The sandy soil was then allowed to rest for 3 years before sprinkling again. The waste is lagooned prior to sprinkling which removes much of the semi-colloidal lignins that tend to clog the soil. It was found that native vegetation, left in place, increased the percolation rate over that of the bare sand. A monitoring well drilled to a clay layer at 90 ft has produced samples showing no trace of contamination.

152 M STREAM POLLUTION - ANIMAL PARASITES IN SEWAGE AND IRRIGATION WATER

Wang, W. L., and S. G. Dunlop
Sewage Ind. Wastes, 26: 1020-1032, August 1954.

Descriptors: Primary effluent, Colorado, Wastewater treatment, Public health regulations.

An investigation was made to determine the efficiency of primary sewage treatment plus chlorination, as practiced in the Denver sewage disposal plant in the removal of animal parasites. The results indicated that about 20 percent of the Ascaris ova and 46 percent of the End. coli cysts found in the raw sewage were still present in the final effluent. However, the sewage treatment showed a removal of over 99 percent of the coliform and enterococci. When the effluent joined the South Platte River and the flow reached Gardeners' irrigation ditch, the number of Ascaris ova and End. coli cysts were found to be reduced considerably. The coliform organisms and enterococci, on the other hand, showed a higher incidence in this ditch than in the effluent. Definite conclusions concerning the public health significance of these findings cannot be stated since little is known of the minimum infecting doses of these organisms.

153 M EFFECTS OF USING LAGOONED SEWAGE EFFLUENT ON FARMLAND

Warrington, Sam L.
Sewage Ind. Wastes, 24: 1243-1247, October 1952.

Descriptors: Wastewater treatment, Human diseases, Recycling nutrients, Salinity.

From a public health standpoint, the degree of treatment and the types of crops grown should be of utmost importance. Where complete treatment is not practiced, the use of the effluent and crops grown should be carefully controlled. Crops which do not come in contact with the water may be grown with comparative safety. In areas where *salt naturally tends to build up, the water should be used with caution. Its salt content, particularly chlorides, should be checked often. The fertilizing value of sewage effluent is great, and when it can be used, the process can convert a liability into an asset.*

154 I SEWAGE EFFLUENT DISPOSAL THROUGH CROP IRRIGATION
Webster, R. A.
Discussion. Sewage Ind. Wastes, 26: 133-135, February 1954.

Descriptors: Public health regulations, Wastewater disposal, Seabrook Farms, New Jersey, Food processing wastes.

The author reviews the history of waste water utilization at Seabrook Farms, Bridgetown, New Jersey. Two distinct advantages are noted: (a) a source of water for crops; and (b) recharge of the groundwater. There has been no evidence of any harmful effects on any potable water (wells) in the immediate vicinity of the spreading area. It has been a happy solution to a waste disposal problem. Before others try the method, the soil should be carefully examined with reference to its absorptive characteristics. The groundwater level should be ascertained to determine the capacity of such a reservoir. Actual tests give the best answers and may save much difficulty later.

155 M DEVELOPMENT AND PRESENT CONDITION OF SEWAGE TREATMENT AND UTILIZATION IN BERLIN
Weiland, K.
Wasserwirt.-Wassertech. (Berlin), 5: 229, 1955. Water Pollut. Abstr., 29: 347(1897), 1956.

Descriptors: Public health regulations, Wastewater disposal, Wastewater treatment, Sprinkler irrigation, Berlin, Germany.

A detailed description is given of the historical development and operation of the Berlin irrigation fields and of the construction and design of the Stahnsdorf and Wassmannsdorf sewage works. The author then discusses the hygiene of agricultural utilization of sewage, the principles of operation, and the necessary precautions and conditions.

156 M SEWAGE DISPOSAL BY LAND IRRIGATION

Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 26: 34, 1952. Abstr., Sewage Ind. Wastes, 24: 1554, December 1952.

Descriptors: Vegetable crops, Wastewater disposal, Human diseases, Economic feasibility, Poland.

A description is given of a land irrigation system in Lower Silesia, which was built in 1906 and has continued in operation to the present time. Data are presented on soil variation with depth in irrigated and nonirrigated soils as well as the humus, P_2O_5 and K_2O contents, and pH changes. Various vegetables are grown, but are not irrigated during the growing season. Workers employed in the fields for over 30 years have had no illnesses or disease outbreaks that could be attributed to the agricultural utilization of sewage wastes.

157 I PONDING AND SOIL FILTRATION FOR DISPOSAL OF SPENT SULPHITE LIQUOR IN WISCONSIN

Wisniewski, T. F., A. J. Wiley, and B. F. Lueck
In: Proc. 10th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1955. p. 480-496.

Descriptors: Wisconsin, Organic loading, Water quality data, Suspended solids, Pulp and paper wastes.

Laboratory, pilot and field scale trials of soil filtration of spent sulfite liquor in Wisconsin suggest the following conclusions: (1) effectiveness of microbial reaction is reduced if loadings exceed the rates of complete reaction; (2) hydraulic loading must be such as to avoid sustained flooding which results in anaerobic conditions; and (3) geological conditions must be such as to avoid groundwater contamination.

If solids loadings are less than 1 lb/sq yd/day (4,800 lb SS/acre/day), BOD removals in excess of 50 percent are possible. Pulp wastes at concentrations of 4 to 8 percent suspended solids were filtered at various rates through various media. BOD removals of 90 percent were obtained in pilot filters using silty clay and loading at 4,600 lb SS/acre/day. At a solids content of 6 percent this organic loading would be equivalent to 9,200 gad in terms of hydraulic loading.

158 M FUNDAMENTAL POINTS ON AGRICULTURAL UTILIZATION OF SEWAGE

Zunker, F.
Wasserwirt.-Wassertech. (Berlin), 5:258, 1955. Water Pollut. Abstr., 29:352(1933), 1956.

Descriptors: Water reuse, Europe, Surveys, Costs, Operation and maintenance.

A detailed survey is given of the requirements and advantages of agricultural utilization of sewage and of the operation and economics of different methods.

SECTION IV

ABSTRACTS 1956 THRU 1960

159 S FERTILIZING CHARACTERISTICS OF SEWAGE SLUDGE
Anderson, Myron S.
Sewage Ind. Wastes, 31: 678-682, June 1959.

Descriptors: Climatic data, Recycling nutrients, Anaerobic digestion, Soil types, United States.

The chemical composition and fertilizer value of sewage sludge depend in part on the method of treatment from which the sludge is obtained. Undigested sludge from secondary treatment has the greatest fertilizer value. Digested sludge from primary treatment has a lower fertilizer value but may be beneficial as a soil conditioner or mulch. The nitrogen content of digested sludge is appreciably lower. Heat treatment is recommended for sanitary purposes before sludge is sold as a fertilizer.

It is important that prospective users be told what to expect from sludge applied to soil. The plant responses will vary with type of soil, kind of plants grown, and climatic conditions.

160 I INDUSTRY UTILIZES SEWAGE AND WASTES EFFLUENTS FOR PROCESSING OPERATIONS
Anonymous
Wastes Eng., 28: 444-448, 1957.

Descriptors: Water reuse, Aerated lagoon effluents.

This article discusses industrial use of sewage and wastes effluents. Several examples of reuse are cited.

161 M DON'T WASTE EFFLUENT

Anonymous
Wastes Eng., 30: 205, April 1959.

Descriptors: Groundwater recharge, Golf courses, Public health regulations, Human diseases, Water reuse.

Especially in water short areas, it is seen that sewage effluent can be put to good use for crops, landscape, decorative lakes and groundwater recharge. The statement is made that no disease transmission or nuisance has been caused by the use of sewage effluent on golf courses.

162 S SEWAGE SLUDGE AS SOIL CONDITIONER

Anonymous
Water Sewage Works, 105: 489, 1958. Pub. Health Eng. Abstr., 39: S: 46.

Descriptors: Greenbelts, Economic feasibility, Sludge disposal, Surveys.

The results of a national survey are presented. Reports the increased sale and demand for sewage sludge to be applied to soil in recent years. Many examples and case histories are cited. Sludge analyses, sales trends, prices, etc., are tabulated for a large number of cities where sludge is sold. Sludge is recommended for lawns, parks, and flower gardens. It deepens the color of grass and stimulates a luxurious growth that is noticeable for longer than one season. It should be applied late in March and again in September, if desired. It provides needed humus as well as a moderate amount of nitrogen to flower garden soils.

163 S SEWAGE SLUDGE AS SOIL CONDITIONER

Anonymous
Water Sewage Works, 106: 424, 1959.

Descriptors: Sludge disposal, Recycling nutrients, Public health regulations, Anaerobic digestion, United States.

This article discusses the use of sewage sludge by farmers and gardners in the United States, methods of processing the sludge and its fertilizer value, how to use the sludge and the safety of using sludge.

164 M TRAVEL OF POLLUTION, AND PURIFICATION EN ROUTE, IN SANDY SOILS
Baars, J. K.
Bull. World Health Organ., 16: 727-747, April 1957.

Descriptors: Netherlands, Groundwater contamination, Soil types.

The travel of pollution in sandy soils, and the extent to which purification takes place en route are discussed, with special reference to the possible contamination of ground water--a problem of particular importance in the Netherlands. Two types of soil pollution are considered: severe pollution of surface layers with matter concentrated in a small volume of water and moderate pollution of the surface layers with matter contained in large quantities of water. Self-purification is sufficient to prevent contamination of the groundwater, provided the soil is very fine, and in the case of the first type--dry and well aerated, and provided that the groundwater level is not too high or the rate of infiltration too great.

165 M PUBLIC HEALTH ASPECTS OF WATER REUSE FOR POTABLE SUPPLY
Berger, B. B.
J. Amer. Water Works Ass., 52: 599-606, May 1960.

Descriptors: Water reuse, Kansas, Water quality data, Human diseases.

The author discusses the feasibility of treating sewage so that the reclaimed water may serve all municipal purposes, including water for drinking. The recent reuse experiences of Chanute and Lyndon, Kansas, are described. It was concluded that modern sewage treatment processes are designed to produce an effluent that will be easily assimilated by the receiving body of water, and that they are not intended to produce a water suitable for a municipal water supply.

166 I STREAM IMPROVEMENT THROUGH SPRAY DISPOSAL OF SULPHITE LIQUOR AT THE KIMBERLY-CLARK CORPORATION, NIAGARA, WISCONSIN MILL
Billings, R. M.
In: Proc. 13th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1958. p. 71-80.

Descriptors: Sprinkler irrigation, Organic loading, Rates of application, Wisconsin, Pulp and paper wastes.

Spent sulfite liquor is sprayed directly on land from tank trucks. The liquid loading rate is 0.3 in./day. Costs exceeded $110,000 for installation not including the cost of the trucks but including pipeline transmission and storage. It was concluded that organic loadings should not exceed 1 lb of solids per square yard per day (4,840 lb/acre/day). The soil system consisted of 70 to 90 feet of sand above the groundwater table.

167 M THE EFFECT OF SPRINKLING IRRIGATION WITH SEWAGE ON THE PRODUCTIVITY OF MEADOWS AND SOME BIOCHEMICAL PHENOMENA IN THE SOIL

Bocko, J.
Chem. Abst., 52: 15808, 1958. Abstr., Soils Fert., 19: 2471, 1956.

Descriptors: Rates of application, Sprinkler irrigation, Soil types, Forage crops.

On deep, light, alluvial soil, increases in hay yields obtained by irrigation with sewage at rates ranging from 90 to 510 mm/ha were directly proportioned to the amount of sewage applied, and amounted to about 2 quintals/ha for each 100 cu.m. of sewage (100 mm/ha). The highest hay yield of 137 quintals/ha was obtained where sewage was applied at the rate of 510 mm/ha. Irrigation with sewage markedly increased the number of bacteria in the surface soil layer.

168 I OBJECTIVES AND PROCEDURES FOR A STUDY OF SPRAY IRRIGATION OF DAIRY WASTES

Breska, G., et al.
In: Proc. 12th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1957. p. 636-652.

Descriptors: Costs, Dairy wastes, Sprinkler irrigation, Wisconsin, Rates of application.

A study was conducted of 6 existing spray irrigation facilities in central Wisconsin. Soils ranged from sandy loams to silt loams. Application rates ranged from 0.13 to 0.29 in./hr. Irrigated and unirrigated soils were analyzed for different chemical and physical characteristics. Capital costs for dairy waste spray irrigation systems ranged from $1,100 to $2,300 per mgd.

169 I COMMINUTED SOLIDS INCLUSION WITH SPRAY IRRIGATED CANNING WASTE
Canham, Robert A.
Sewage Ind. Wastes, 30: 1028-1049, August 1958.

Descriptors: Sprinkler irrigation, Economic feasibility, Clogging (soil), Minnesota, Food processing wastes.

Although spray irrigation of liquid wastes was known to be successful, the separate disposal of solids was expensive and the possibility of using spray irrigation was explored. The study concluded that spray irrigation with solids is feasible and economical provided mechanical difficulties of grinding and clogging are overcome. The soil of this field in Montgomery, Minnesota, ranged from poor to well drained and absorbed seven inches of waste in 45 days.

170 I INDUSTRIAL WASTE DISPOSAL BY SPRAY IRRIGATION
Canham, Robert A.
Southwest Water Works J., 41: 14-16, 18, 20, 22, 1959.

Descriptors: Sprinkler irrigation, Odor, Costs, Soil types, Forage crops.

The author discusses the many advantages of waste disposal by spray irrigation. Among these are: (1) affords complete and adequate treatment; (2) minimizes offensive odors; (3) cost of operation compares favorably with other disposal methods; and (4) does not require highly trained personnel.

Soil characteristics and cover crops are important considerations for successful operation. Recommends that wastewaters be screened before spraying.

171 M SPRAY DISPOSAL OF DOMESTIC WASTES
Chase, William J.
Pub. Works, 91: 137-141, May 1960.

Descriptors: Spray disposal, Vegetation damage, Soil types, Ion exchange.

Emphasizes the need for proper disposal methods in relation to spray irrigation of pasture and wooded areas with domestic wastes. Requirements are given in regard to pretreatment, allowable volumes according to conditions, spray-nozzle arrangement, prevention of harm to foliage, and other details of application. Deep silty soil is preferable. Clay subsoil may lead to bad effects from adsorption of sodium through ion-exchange.

172 M UTILIZATION OF WASTE WATERS
Connell, C. H.
Ind. Wastes, 2: 148-151, 1957. Pub. Health Eng. Abstr., 38: S: 50.

Descriptors: Texas, Water reuse, Wastewater disposal, Operation and maintenance.

In Texas, indirect reuse of water can seldom be practiced because few streams have sufficient flow to dilute and purify a plant effluent and carry it to a downstream water intake. Texas uses more sewage effluents for cooling and boiler makeup water than any other state. The total use of these waters in Texas is less than 4 mgd, or about one-half the total amount of such waters used in the U. S. The big users of sewage effluents are the Cosden Petroleum Corporation of Big Spring, Texas, and the Texas Company of Amarillo, Texas.

173 M INDUSTRIAL UTILIZATION OF MUNICIPAL WASTEWATER
Connell, C. H., and E. J. M. Berg
Sewage Ind. Wastes, 31: 212-220, February 1959.

Descriptors: Wastewater disposal, Water reuse, Public health regulations.

Industrial use of municipal wastewater constitutes approximately one percent of the total available. The potential use may be as high as 25 percent.

Experience, to date, indicates that municipal wastewater can and should be given more consideration as a source of industrial water supply. This may lead to increased use, especially in areas where competition for water is increasing. Nineteen industrial plants are listed that now use municipal wastewater supply. No adverse health effects have been observed in such usage.

174 I SPRAY IRRIGATION OF CERTAIN SULFATE PULP MILL WASTES
Crawford, S. C.
Sewage Ind. Wastes, 30: 1266-1272, October 1958.

Descriptors: Virginia, Rates of application, Soil physical properties, Pulp and paper wastes, Sprinkler irrigation.

Kraft pulp mill wastes from the Union Bag-Camp Corp. plant at Franklin, Virginia, were disposed of by spray irrigation. Evaporator condensate, digester condensate and dregs washings amounting to 1 mgd were lagooned prior to spraying. Application rates to the highly permeable Norfolk sand were 3.6 in./wk. Wastes were sprayed at 0.45 in./hr for 8 hr once a week on each 10 acre plot. Crops grown included corn, peanuts, soybeans, tomatoes, and melons. Some 50 acres of woodlands were also sprayed. The wooded areas received more than 3.6 in./wk and some ponding has occurred. The total land and installation costs amounted to $75,000.

175 M HAY PRODUCTION OF SMALL GRAINS UTILIZING CITY SEWAGE EFFLUENT
Day, A. D., and T. C. Tucker
Agron. J., 52: 238-239, 1960.

Descriptors: Southwest U.S., Forage crops, Water reuse.

City sewage effluent can be utilized efficiently to produce hay from small grains in the irrigated areas of the Southwest and possibly elsewhere in the United States and the world where small grains benefit from supplemental irrigation water and fertilizer.

176 M PRODUCTION OF SMALL GRAINS PASTURE FORAGE USING SEWAGE EFFLUENT AS A SOURCE OF IRRIGATION WATER AND PLANT NUTRIENT
Day, A. D., and T. C. Tucker
Agron. J., 51: 569-572, 1959.

Descriptors: Grain crops, Wastewater disposal, Sprinkler irrigation, Recycling nutrients, Tucson, Arizona.

Barley, oats and wheat produced superior yields when irrigated with sewage effluent as compared to well water. Yields of barley were 212 percent times the well water control, wheat was 363 percent higher than its control and oats yields were 349 percent of its control. When compared to well water with the fertilizing equivalents of sewage, both oats and wheat yields were still superior, while barley yields were 22 percent less.

177 S SALE OF "RAPIDGRO" GIVES GRAND RAPIDS $150,000 REVENUE FROM DRIED SLUDGE
Delano, E. H.
Wastes Eng., 28: 30-31, 1957.

Descriptors: Michigan, Costs, Operation and maintenance, Surveys.

The city of Grand Rapids has produced an organic soil builder from its sewage treatment plant since 1932. In the past 14 years, its dried sludge sales have totaled $150,975 against operating costs of $87,771. Analyses of the sludge are given. The cost and other manufacturing aspects of "RAPIDGRO" production are discussed in detail.

178 I WATER USE IN INDUSTRY
Derby, Ray L.
Amer. Soc. Civil Eng., J. Irrigation Drainage Div., 83(IR2): 1-9, June 1957.

Descriptors: Water reuse, Water quality data, Costs, Water quality standards.

This article briefly discusses the three major considerations of industrial water use: quantity, quality, and reuse. A listing of the average water use in some typical industries is presented. Methods of water treatment are divided into seven classes, and water quality requirements for various industries are given. The savings in cost and in water quantity requirements brought about by the reuse of water are considered.

179 I CANNERY WASTE DISPOSAL AT GERBER PRODUCTS
Dietz, Max R., and Ray C. Frodey
Compost Sci., 1: 22-25, March 1960.

Descriptors: Food processing wastes, Sprinkler irrigation, Michigan.

Spray irrigation as a means of disposing of cannery wastes has given satisfactory results at the Fremont, Michigan plant of Gerber Products Company. The operation is described.

180 M CROP IRRIGATION WITH SEWAGE PLANT EFFLUENT
Dye, E. O.
Sewage Ind. Wastes, 30: 825-828, 1958.

Descriptors: Wastewater disposal, Sprinkler irrigation, Recycling nutrients, Public health regulations, Tucson, Arizona.

Irrigation with sewage effluent makes use of water which contains some nutritional value and which is usually wasted. It aids the economy of an area and reduces the pollution loads on a watercourse, especially a dry stream. With few adaptions, it produces no hazards to operators and others. Numerous facts are now available favoring the use of sewage effluents for crop production. Sound sanitary principles are required in application. The increased yield of farm products is a major inducement.

181 ! SPRAY IRRIGATION OF FOOD PLANT WASTE WATERS
Ebbert, S. A.
Presented at the 30th Annual Meeting, Federation of Sewage and Industrial Wastes Associations, University Park, Pennsylvania, August 13-15, 1958.

Descriptors: Food processing wastes, Odor, Groundwater recharge, Sprinkler irrigation, Pennsylvania.

Spray irrigation is attractive to canners for four reasons: (1) its relative economy compared to other treatment methods, (2) complete elimination of stream pollution, (3) absence of odors, and (4) potentials that may benefit the canners such as groundwater recharge, nutrient addition to soils, and irrigation of edible crops. The land area required is dependent upon soil type, cover crops, temperature, humidity, canning season, and rainfall. Slopes up to 8 percent have been observed to be successful, but maximum slopes are dependent upon soil characteristics, cover crop, and application rate.

Crops such as peas, corn, and grains have been used with limited success but usually result in over-watering. Natural wooded areas with application rates 10 times as high as open land have been reported. Other design guidelines are given for screening, pumping, distribution, and spray nozzles. Considerations for future study include (1) pH limits for crops and soils, (2) tolerances for wooded area applications, (3) effect of including comminuted solids, and (4) effects on crops.

182 S SLUDGE UTILIZATION AND DISPOSAL
Fleming, J. R.
Sewage Ind. Wastes, 31: 1342-1346, November 1959.

Descriptors: Sludge disposal, Recycling nutrients, Southeast U.S., Surveys, Fertilizer value.

Presents a resume of general methods of sludge disposal and summarizes methods used in 28 towns in Alabama, Arkansas, Florida, Kentucky, South Carolina, and Tennessee. Soil conditioning and fertilizer value of digested sludge are discussed, as are problems associated with the agricultural use of sludge.

183 I DISPOSAL OF PULP AND PAPERMILL WASTE BY LAND APPLICATION AND IRRIGATION USE

Gellman, I., and R. O. Blosser
In: Proc. 14th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1959. p. 479-494.

Descriptors: Pulp and paper wastes, Soil physical properties, Microbial degradation, Sprinkler irrigation, Reviews.

Some of the reasons for increased attention being given land disposal of mill effluents are briefly reviewed. Factors considered important to such disposal are: physical characteristics of the soil, microbial activity, and organic decomposition in the soil. Current land and crop irrigation practices are discussed. Water quality as required for irrigation and the problem of water salinity are considered. Results of 18 mill studies are summarized and additional studies suggested.

184 M SEWAGE SALINITY PREVENTS USE OF EFFLUENT FOR GOLF COURSE IRRIGATION

Guymon, Boyd E.
Wastes Eng., 28: 80-83, 1957.

Descriptors: Sprinkler irrigation, Golf courses, Salinity, California, Costs.

The salinity of the treated sewage of the city of Coronado, California, was found to be too high to permit its use for irrigating a proposed 18-hole public golf course on land bordering San Diego Bay. The annual cost of irrigating the tract with the municipal supply was estimated to be $26,000. The author presents salinity data for both the public water supply and the sewage, covering a typical 24-hour day. A method of separating the merging flows of two main outfall sewers, one high in salinity and the other acceptable, is illustrated and briefly explained.

185 M WATER REUSE IN TEXAS
Gloyna, E. F., W. R. Drynan, and E. R. Hermann
J. Amer. Water Works Ass., 51: 768-780, June 1959.

Descriptors: Costs, Texas, Water reuse, Wastewater disposal, Water quality standards.

The possible reuse of wastewater throughout the eastern one-third of Texas was investigated. The factors studied were: (a) wastewater quantity; (b) criteria of quality; (c) needs and cost of reclamation; (d) effects of public opinion on such reuse; and (e) administration of the reuse program. Numerous data were collected, calculations made, and the results presented in tabulations and graphs.

186 M THE BEEF TAPEWORM, MEASLY BEEF, AND SEWAGE--A REVIEW
Greenberg, A. E., and B. H. Dean
Sewage Ind. Wastes, 30: 262-269, March 1958.

Descriptors: Arizona, Forage crops, Human diseases, Primary effluent.

In man, the tapeworm lives in the intestinal tract and discharges ripe eggs with the feces of its host. Cattle become infected by ingesting contaminated water or grass. The eggs hatch in cattle, the larvae migrate to muscle tissue, and the larvae become encased in cysts or measles. The cycle is completed by man eating raw or rare measly beef.

Measles were observed in beef grazed on Melbourne's sewage farm in 1933. In Arizona, 23 of the 45 cattle grazing on the sewage farm irrigated with primary effluent were infected with beef measles. Conventional sewage treatment operations are inadequate in the removal of tapeworm eggs, however, sand filtration or microstraining will remove eggs completely.

187 M IRRIGATION AND UTILIZATION OF SEWAGE RESIDUES (HYGIENIC REGULATIONS)
Harmsen, H.
Staedteh. (Hamburg), 8; 25-27, 1957. Water Pollut. Abstr., 30: 385(2182), 1957.

Descriptors: Human diseases, Surveys, Sprinkler irrigation, Legal aspects, Germany.

In view of the objections raised, especially from a hygienic point of view, to the provisions of DIN 19650 issued in 1956 and dealing with irrigation and the use of sewage, the author surveys work done and legal enactments on the hygienic problems of use of sewage on land.

188 M TEXAS APPROVES IRRIGATION OF ANIMAL CROPS WITH SEWAGE PLANT EFFLUENTS

Herzik, G. R., Jr.
Wastes Eng., 27: 418-421, 1956.

Descriptors: Vegetable crops, Texas, Primary effluent, Public health regulations, Economic feasibility.

The author reviews the findings of Willem Rudolfs, et al., of Rutgers, concerning the growing of vegetables in polluted soil. Also refers to other work relative to bacteria and virus infections of raw vegetables.

In June 1952, the Texas Board of Health approved a resolution defining its stand on this matter, as follows:

> *"The use of raw or partially treated sewage or the effluent from a sewage treatment plant is prohibited for use as irrigation water on any food crop which might be consumed in the raw state. Such practice is the deliberate exposure of food to filth as defined by Art. 707 of our Texas Penal Code."*

Outlines the point of view of the State Department of Health regarding the public health aspects of sewage irrigation as follows:

1. *Do not favor use of raw sewage for irrigation regardless of type of crop. Sewage effluent receiving at least primary treatment may be used for irrigation, but not for crops for human consumption. Encourages use of primary-treated, and preferably completely treated, sewage on feed and pasture crops used for animal consumption, or as an adjunct to soil conservation practices.*

2. *The practice should be followed in such a way as to prevent the creation of a public health hazard, nuisance, or stream pollution.*

3. *If handled properly, the sewage used at an irrigation farm should not be hazardous to the operators.*

4. *Sewage sludge has certain soil conditioning and fertilizing characteristics. It likewise is not recommended for use on crops for human consumption.*

5. *Sewage irrigation makes use of water that is usually wasted, aids the area economy, reduces pollutional loads on streams, and is not hazardous to the operators. From these considerations, its continued favorable consideration is heartily endorsed.*

189 M UTILIZATION OF SEWAGE FOR CROP IRRIGATION IN ISRAEL
Heukelekian, H.
Sewage Ind. Wastes, 29: 868-874, August 1957.

Descriptors: Odor, Economic feasibility, Activated sludge effluents, Sprinkler irrigation, Israel.

Distinction is drawn between the disposal of sewage on land and the utilization of sewage for crop production. Failures and difficulties encountered with the former need not arise when utilization is the main objective. With land disposal systems, the tendency is to apply more sewage to a limited area than can percolate through the soil. Waterlogging of the soil and odors result. When application is geared to the needs of the soil and crop, these problems do not arise. Under proper climatic and soil conditions and with proper control, irrigation with sewage effluents need not create nuisance conditions or health hazards. In certain areas of the world, crop irrigation is an economic necessity for the development of agriculture and, at the same time, it can solve the sewage disposal problem.

Sewage effluents are proposed as a resource to augment present water supplies and allow further expansion of irrigated agriculture. Factors affecting the successful utilization of sewage for crop production are discussed. Two alternatives for the treatment of irrigation sewage are suggested:

1. *The sewage could be subjected to secondary treatment and thorough disinfection and the effluent used for unrestricted crop irrigation.*

2. *The sewage could be given minimum treatment and the effluent utilized without disinfection for irrigation of crops not eaten raw by human beings.*

Experiments are described which compared sewage irrigation with municipal water supply. Significantly greater yields on sewage-irrigated plots were attributed to regular supply of nutrients throughout growing season instead of just at beginning.

190 M SEWAGE REUSE (Literature Review)
Heukelekian, H. (Chairman)
Sewage Ind. Wastes, 31: 534-536, May 1959.

Descriptors: Rates of application, Sprinkler irrigation, Europe, Groundwater recharge, Reviews.

This review of the literature of 1958 tells of many examples of sewage effluent reuse for irrigation and groundwater recharge. In Israel, it is used in an area of sand dunes at the rate of 85,000-100,000 gpd per acre, ten times the agricultural irrigation rate. Eastern European countries have obtained yields 5-6 times the normal by using sewage for irrigation. In recharging, bacteria have been found to move only 100 feet maximum with the water, practically insuring that this pollution will not affect groundwater sources.

191 I SPRAY IRRIGATION OF WOOD DISTILLATION WASTES
Hickerson, R. C., and E. K. McMahon
J. Water Pollut. Contr. Fed., 32: 55-64, January 1960.

Descriptors: Sprinkler irrigation, Wastewater disposal, Organic loading, Forage crops.

Spray irrigation seems particularly suited for nontoxic, high BOD, water-soluble organic wastes. Greenhouse and field tests were run, using fescue, blue grass, rye grass and ladino clover.

Utilization of these wastes for irrigation greatly alleviated a stream pollution problem. It proved a useful and practical means for industrial waste disposal at the Wrigley wood distillation plant.

Steps to be followed in evaluating a particular waste disposal problem are suggested.

192 I EVALUATION OF BROAD FIELD DISPOSAL OF SUGAR BEET WASTES
Hopkins, Glen, Joe Neel, and Francis Nelson
Sewage Ind. Wastes, 28: 1466-1474, December 1956.

Descriptors: Nebraska, Spray disposal, Water quality data, Nutrient removal, Surveys.

In a continuation of a project begun in 1953, industrial wastes from the Great Western Sugar Company in Bayard, Nebraska, were applied to a field as a treatment process. Significant waste load reductions were realized for SS, turbidity, BOD, and nitrogen. Phosphates were unchanged while coliforms increased. The test was run in late October, when temperatures range from highs of 56-78° F to lows of 21-37° F at night.

193 I SPRAY IRRIGATION USES CANNERY WASTES

Jackson, Frank A.
West. Canner Packer, 49: 14-15, November 1957.

Descriptors: Washington, Wastewater disposal, Forage crops, Overland flow, Costs.

The Green Giant Company in Dayton, Washington, utilized a 20-acre plot to dispose of canning wastes at a rate of 4 inches every 5 days. The cover crop is grass and although some problems of ponding and runoff were encountered, it is now a successful operation at a reasonable cost.

194 M UTILIZING THE DECOMPOSITION OF ORGANIC RESIDUES TO INCREASE INFILTRATION RATES IN WATER SPREADING

Johnson, Curtis E.
Trans. Amer. Geophysical Union, 38: 326-332, 1957.

Descriptors: Nitrification, Soil types, Microbial degradation, Rates of application.

Decomposition rates were determined for several plant residues which were incubated under controlled conditions in the absence of soil. Three, ranging in rates from high to low, were mixed with soil and incubated. Decomposition rates with soil were similar to those without soil. Microbial counts made during decomposition of the plant residues in soil showed the greatest number of microorganisms occurred in the soils containing plant residues which decompose rapidly. Ammonium nitrate mixed with the soil stimulated decomposition slightly.

Percolation rates of soil mixed with organic residues varied with the amount of material applied, decomposition rate of the material, and length of the incubation period. The studies indicate that initial decomposition at a moisture content near field capacity, followed by decomposition at *near saturation, produces the highest infiltration rate for a given amount of organic residue. Data are given and the use of organic residues to increase the infiltration rate of water-spreading areas is discussed.*

195 M NOT A DROP WASTED
Johnson, William E.
Amer. City, 73: 111-112, February 1958.

Descriptors: Washington, Forage crops, Grain crops, Sprinkler irrigation.

The city of Ephrata, Washington, sells its effluent to be used for irrigation. Hay and corn are the principal crops grown. Presently, 80 acres are being irrigated.

196 I EXPERIMENTAL SPRAY IRRIGATION OF PAPERBOARD MILL WASTES
Koch, Harold C., and D. E. Bloodgood
Sewage Ind. Wastes, 31: 827-835, July 1959.

Descriptors: Forage crops, Ohio, Pulp and paper wastes, Rates of application, Sprinkler irrigation.

Paper mill effluent was successfully applied to land planted in alfalfa at St. Mary's, Ohio, through both summer and winter months. The effluent receives treatment of screening and is pumped to the field at a water temperature of about 90° F. Average rate of application was 0.28 inches per day, of which 0.08 inches is rainfall. Crop yields were called very good and no damage to soil or plants was noted, even after the winter spraying.

197 M UTILIZATION OF SEWAGE FOR IRRIGATION
Kowalski, J.
Nasa Veda (Czechoslovakia), 6: 68-72, 1959. Water Pollut. Abstr., 28: 93 (467), 1959.

Descriptors: Czechoslovakia, Economic feasibility, Sprinkler irrigation, Wastewater treatment.

On the basis of calculations to determine the most economical method of sewage treatment for Bratislava, Czechoslovakia, the author recommends disposal by irrigation.

198 M DIRECT DISCHARGE OF GROUND WATER WITH SEWAGE EFFLUENTS

Krone, R. B., P. H. McGauhey, and H. B. Gotaas

Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 83(SA4): 1-25, August 1957.

Descriptors: Raw sewage, Groundwater recharge, Groundwater movement, Activated sludge effluents, California.

This paper presents the conclusions of a three year study of the technical feasibility and public health safety of injecting sewage effluent directly into underground aquifers conducted by the Sanitary Engineering Research Laboratory, U.C. Berkeley under the sponsorship of the California State Water Pollution Control Board.

Mixtures of settled raw sewage and water were used to recharge a 5-ft thick confined aquifer located 95 ft underground. Observation of pressure and of pollution travel were made in 23 sampling wells surrounding the recharge well.

It was found that bacterial pollutants traveled a maximum of 100 ft in the direction of normal groundwater movement even though steep gradients were imposed. (Coliform concentration of 2.4×10^6 *per 100 ml produced counts up to 23 organisms per 100 ml at a distance of 100 feet from recharge well). The maximum distance of travel was quickly reached, but intensity of pollution regressed as the aquifer faced in the recharge well became increasingly clogged. Sewage approximating the final effluent from secondary sewage treatment in terms of suspended solids, could be successfully injected underground through the experimental recharge well at a rate equal to about one-half the safe yield of the well. It was found that the well could be redeveloped to restore its original characteristics, after clogging has progressed to any maximum limit consistent with safety. An injection rate of 8.4 gpm/sq ft of aquifer, equal to the best reported for fresh water recharge, was found to be practical.*

199 M MOVEMENT OF COLIFORM BACTERIA THROUGH POROUS MEDIA

Krone, R. B., G. T. Orlob, and C. Hodgkinson

Sewage Ind. Wastes, 30: 1-13, January 1958.

Descriptors: Coliforms, Wastewater treatment, Soil types, Deep percolation.

Research was conducted on bacterial movement through four sand columns. The removal of bacteria was found to be by straining and by sedimentation. When the voids near the soil surface become sufficiently filled to remove bacteria by straining, the straining removal rate increases.

The sedimentation removal mechanism has a relatively great saturation capacity. Its removal rate is a function of the flow rate and the size and density of the bacterial cluster. This mechanism becomes saturated first at the soil surface and controls the subsequent passage of bacteria.

200 M SPRAY IRRIGATION FOR THE REMOVAL OF NUTRIENTS IN SEWAGE TREATMENT PLANT EFFLUENT AS PRACTICED AT DETROIT LAKES, MINNESOTA
Larson, W. C.
In: Algae and Metropolitan Wastes--Transactions of the 1960 Seminar. U.S. Dept. Health, Education and Welfare, Washington, D.C., 1960. p. 125-129.

Descriptors: Minnesota, Costs, Vegetation damage, Nutrient removal, Sprinkler irrigation.

This report gives a case history of a problem at Detroit Lakes, Minnesota. An abnormal algae bloom in a recreational lake caused a fish kill. The solution decided upon was to spray irrigate a 4-acre tract of wooded land. Heavy application of effluent (0.3 in./hr for 20 hr) killed some trees. Because of the gravel nature of soil, little removal was accomplished. Samples from a test well indicate that all minerals in the analysis increased in concentration. Installation costs are included.

201 I SPRAY IRRIGATION OF DAIRY WASTES
Lawton, Gerald W., et al.
Sewage Ind. Wastes, 31: 923-933, August 1959.

Descriptors: Wisconsin, Dairy wastes, Sprinkler irrigation, Organic loading.

About 30 milk plants in Wisconsin use spray irrigation for the disposal of wastes. It has proven to be satisfactory and economical. Of prime consideration are volume of wastes and the cations present; BOD loading is much less significant. Winter spray irrigation is possible, but the resulting ice usually kills the cover crop. Alternates, such as ridge and furrow irrigation, have been successful.

202 I EFFECTIVENESS OF SPRAY IRRIGATION FOR THE DISPOSAL OF DAIRY PLANT WASTES
Lawton, G. W., et al.
Wisconsin Univ. Eng. Exp. Sta. Res. Rep. 15, Madison, Wis., 1960. 59 p.

Descriptors: Dairy wastes, Wisconsin, Spray disposal, Odor, Soil types.

The use of spray irrigation of dairy wastes was studied in detail at five Wisconsin farms near Madison. The conclusion of this study was that this method is practical, satisfactory and economical although disposal of wastes in winter necessitated the use of another method. Realistic average application rates of 0.23 inch per hour were realized with cover crops of blue grass, quack and brome. Odor problems were minimal except in operations where ponding was allowed to occur. Soil ranged from sand to sand loam and loams.

203 S SLUDGE DISPOSAL PRACTICES IN THE PACIFIC NORTHWEST

Leaver, R. E.
Sewage Ind. Wastes, 28: 323-328, March 1956.

Descriptors: Washington, Recycling nutrients, Economic feasibility, Wastewater disposal, Costs.

Summarizes the sludge disposal practices at several communities in the Pacific Northwest, principally the State of Washington. Four communities are cited as typifying current practice in the disposal of liquid sludge. Some of it is sold, and some is free to private haulers. Other examples are cited in which communities dispose of air-dried digested sludge and filter-dried sludge. Income from sales is given. Fertilizing ingredients are compared in tabular form for various types of sludge, manures, and other organic materials. The Washington State Department of Health, "General Guide for the Utilization and Disposal of Sewage Sludge," is presented as an appendix to the report.

204 I EFFECT OF CANNERY WASTE REMOVAL ON STREAM CONDITIONS

Lunsford, J. V.
Sewage Ind. Wastes, 29: 428-431, April 1957.

Descriptors: Washington, Sprinkler irrigation, Water quality data, Rates of application, Forage crops.

The Green Giant Cannery in Dayton, Washington, used spray irrigation of wastes advantageously, greatly improving stream quality in terms of BOD and DO. The wastes, having an average BOD of 5000 ppm were pumped at a rate of 1.92 mgd to 100 acres of land, 80 of asparagus and 20 of pasture grass. Applying at a rate of 4 inches per day every 5 days, ponding resulted, causing much of the grass to yellow. However, after the cessation of the spraying after 6 weeks of operation, superior crop yields were realized.

205 M DRAINAGE OF AGRICULTURAL LANDS, Madison
Luthin, J. N. (ed.)
Amer. Soc. Agronomy, Monogram Series No. 7, 1957. 620 p.

Descriptors: Tile drainage, Wastewater disposal, Subsurface drainage.

Theoretical, engineering and investigative aspects of land drainage are discussed. Drainage problems of irrigated lands are generally caused by over-irrigation and seepage from canals delivering the irrigation water. Drainage is important not only to remove excess water but also to provide a medium for the removal of salts from the soil where evapotranspiration exceeds precipitation. Tile drains, open ditches, or drainage wells are used for subsurface drainage. The effect of land drainage on soils and crops is also discussed.

206 I DAIRY WASTES: DISPOSAL BY SPRAY IRRIGATION ON PASTURE LAND
McDowall, F. H.
Dairy Eng., 75: 251-254, 266, 1958.

Descriptors: New Zealand, Sprinkler irrigation, Wastewater disposal, Dairy wastes.

The author discusses the disposal of effluents from New Zealand dairies by irrigation and describes a typical installation using high-pressure rotating sprays and a suitable irrigation technique. He gives the reasons why this method is particularly applicable in New Zealand.

207 M THE WHY AND HOW OF SEWAGE EFFLUENT RECLAMATION WATER AND SEWAGE
McGauhey, P. H.
Water Sewage Works, 104: 265-270, 1957.

Descriptors: Groundwater recharge, California, Economic feasibility, Flood irrigation.

The author discusses the need for sewage reclamation in California and the amount of water available from sewage. The total volume of water which could be reclaimed would be only eight percent of that required for crop irrigation but would be of more value for industry and irrigation purposes in towns. Sewage effluent can be used to recharge groundwater supplies by spreading on the soil. The bacteria present are removed during the first four feet of travel through the soil. Groundwater may also be recharged by direct injection of effluent into water-bearing strata. Bacteria do not travel more than 100 feet in moving *groundwater. The author considers the present use of effluents and suggests methods of increasing future use.*

208 M DAIRY WASTE DISPOSAL BY SPRAY IRRIGATION
McKee, Frank
Sewage Ind. Wastes, 29: 157-164, February 1957.

Descriptors: Water reuse, Dairy wastes, Sprinkler irrigation, Canada, Odor.

Dairy plants, often relatively small and rurally located, find that disposal of processing wastes is an acute problem. Disposal of their wastes to the city sewage treatment plant, if one exists, is undesirable because the wastes are not adequately treated by conventional means. However, spray irrigation has been successfully used as far north as Berwick, Ontario, Canada, and elsewhere at rates up to 10,000 gpd per acre. Winter operations have been successfully carried out in some locations with buried pipes, while other facilities use other systems during freezing weather. Runoff and odor problems have been minimal.

209 I EXPERIMENTAL SPRAY IRRIGATION OF STRAWBOARD WASTES
Meighen, A. D.
In: Proc. 13th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1958. p. 456-464.

Descriptors: Indiana, Rates of application, Soil types, Pulp and paper wastes, Sprinkler irrigation.

An experimental 4.5 acre plot was sprayed with strawboard wastes at rates of 0.25 in./day, 0.5 in./day and 1.2 in./day. Some ponding occurred at the latter two rates, however, a tremendous crop of horse weeds grew on the field to a height of 8-10 ft. It appears that the sandy loam soil used can accept the 0.25 in./day of spray at the Terre Haute Mill of the Weston Paper and Manufacturing Co. in Indiana.

210 S REPORT ON CONTINUED STUDY OF WASTE WATER RECLAMATION AND UTILIZATION
Merz, Robert C.
Calif. State Water Pollut. Contr. Board, Publ. No. 15, Sacramento, June 1956. 90 p.

Descriptors: California, Oxidation lagoons, Surveys, Economic feasibility, Water reuse, Bibliographies.

A continuation of the study reported in Publication No. 12 (1955). Reports on the progress of two principal studies. The first concerned reclamation of liquid, digested sludge in San Diego County for a twofold purpose: enrichment of waste lands; and lessening of the pollution of San Diego Bay. The other concerned reclamation of a raw sewage lagoon effluent at Mojave, California, also for a twofold purpose: providing a Marine Air Base with suitable, economical, irrigation water; and demonstrating that the raw sewage lagoon, when well designed and operated, can be an adequate means of sewage treatment for the small, desert community. Conclusions and recommendations are summarized. A short bibliography and 22 pertinent abstracts are included.

211 M DIRECT UTILIZATION OF WASTE WATERS

Merz, Robert C.
In: Proc. 11th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1956. p. 541-551.

Descriptors: Golf courses, Recreational facilities, Climatic data, Economic feasibility, Water reuse.

A survey shows that more than 150 industries in 38 states reclaim industrial wastes, and about 15 in nine states employ sewage effluent. The primary reason is that there are significant savings. Specific examples are cited.

Land and climate are the primary factors affecting agricultural utilization of wastewater. Several successful operations are described. Restrictions are the amount of water to be disposed of, quality of the effluent, and health regulations.

Other direct utilization is employed for recreational areas (golf courses, decorative lakes, parks, etc.) and groundwater recharge. The author states, "The investigations made thus far indicate strongly that the reclamation of sewage effluents is a sound practice for industry, agriculture, and other uses."

212 M THIRD REPORT ON THE STUDY OF WASTE WATER RECLAMATION AND UTILIZATION

Merz, R. C.
Calif. State Water Pollut. Contr. Board, Publ. No. 18, Sacramento, August 1957. 102 p.

Descriptors: Aerosols, Water quality data, California, Forage crops, Sprinkler irrigation.

The Talbert Valley Water District operation demonstrated a significant utilization of wastewater for agricultural use. It concludes that it is possible for a group of private farmers to organize, finance and construct a reclamation system to utilize a sewage effluent for economical irrigation of field crops, within the requirements of state and local authorities. The separation of industrial wastes from the domestic wastes is necessary to maintain irrigation water quality. An opportunity exists to obtain further data on the effect on crops of irrigation with primary effluent, and to evaluate operating problems directly related to public health acceptance.

Also included is a study on spreading of bacteria through aerosols using spray irrigation. With a 5 to 10 mph wind, the maximum limit of the mist zone extended 105 ft downwind from a sprinkler which had a 30 ft normal spray radius.

213 M WATER RECLAMATION AND REFUSE DISPOSAL
Merz, Robert C.
Water Sewage Works, 105: 306-307, July 1958.

Descriptors: Sprinkler irrigation, Water reuse, California, Surveys, Costs, Groundwater recharge.

This report summarizes the reports of five speakers at the forum. Settled sewage from Santa Ana irrigates 2,250 acres growing alfalfa and sugar beets, and on a pre-irrigation basis, lima beans and chili peppers. San Bernardino sells effluent for irrigation, but plans to improve the treatment process and use the effluent for recharging the groundwater. Golden Gate Park uses 0.75 mgd from the San Francisco treatment plant. Contemplated plant improvements will make 5 mgd available for irrigation. Oceanside will use oxidation ponds for final treatment to prepare its sewage effluent for commercial and irrigation use. A Marine Corps base in the Imperial Valley pays $55 per acre-ft for water piped in from 15 miles away. Reclaiming its sewage plant effluent by pond treatment and using it for irrigation and flushing will effect an annual savings of $24,000.

214 S UTILIZATION OF LIQUID SLUDGE
Merz, Robert C.
Water Sewage Works, 106: 489-493, 1959.

Descriptors: Land reclamation, California, Costs, Sludge disposal, Recycling nutrients.

A method for reducing the cost of treatment plant operation plus reclamation of waste land is presented. The city of San Diego has found land disposal a satisfactory and practical method of utilizing the liquid digested sludge produced at its sewage treatment plant. Sludge-drying facilities have been shut down, and all sludge is now utilized for soil improvement. The value of organic matter in the soil for maintaining and storing moisture is well known.

The San Diego liquid sludge disposal operation has shown that (a) waste land can be reclaimed for agriculture with liquid sludge of reasonable solids content at less cost than with dried sludge; (b) sludge loadings as high as 100 tons dry solids per acre can be applied without impairing crop growth; (c) sludge loadings as low as 25 tons dry solids per acre will produce crop growth comparable to that achieved by the use of commercial fertilizer at conventional application rates; (d) an initial sludging with 50 tons dry solids per acre will grow a second superior crop due to residual fertilization not used up by the first; and (e) it is possible to avoid serious sludge handling or nuisance problems.

215 M WASTE WATER RECLAMATION FOR GOLF COURSE IRRIGATION

Merz, Robert C.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 85(SA6): 79-85, December 1959.

Descriptors: California, Golf courses, Sprinkler irrigation, Disinfection, Odor, Public health regulations.

Three years' experience at municipal and military golf courses shows that reclaimed wastewater can be properly used for irrigation purposes. Value is derived from the fertilizing constituents. Difficulties may arise in certain soils due to increased sodium content of the water. Chlorination will prevent odor nuisance as well as the spread of B. coli through wind action.

216 M IRRIGATION WITH SEWAGE IN AUSTRALIA

Muller, W.
Wasser Boden (Hamburg), 7: 12, 1955; Zb. Bakt. I, Ref., 1956, 159: 503.
Water Pollut. Abstr., 20: 202(1108), 1956.

Descriptors: Water reuse, Wastewater disposal, Australia, Forage crops, Fruit crops.

The author gives an account of the conditions under which sewage is used for irrigation in Australia. Only settled and biologically treated sewage *may be used. Surface irrigation is preferred. The amounts vary from 350 to 7,500 mm. per year. Land for pasture use and fruit growing is irrigated.*

217 S DIE INFEKTION VON GEMUSEPFLANZEN DURCH DIE BEREGNUNG MIT HAEUSLICHEM ABWASSER (INFECTION OF VEGETABLES BY APPLICATION OF DOMESTIC SEWAGE AS ARTIFICIAL RAIN)
Muller, Gertrud
Staedteh. (Hamburg), 8: 30-32, 1957.

Descriptors: Sprinkler irrigation, Vegetable crops, Flood irrigation, Pathogenic bacteria, Germany.

The author describes experiments in which plots of land, on which carrots, cabbages, potatoes, and gooseberry bushes were growing, were watered with settled sewage. The soil, vegetables, and fruits were tested for the presence of Bact. coli and Salmonella at intervals up to 40 days after application of sewage. The amounts of sewage used were small, but Salmonella were detected in the soil and on the potato tubers after 40 days, on carrots after 10 days, and on cabbage leaves and gooseberries after 5 days.

218 M SANITARY ENGINEERING APPRAISAL OF WASTE WATER REUSE
Ongerth, Henry J., and Judson A. Harmon
J. Amer. Water Works Ass., 51: 647-658, May 1959.

Descriptors: Water reuse, Legal aspects, Public health regulations, Economic feasibility.

This article briefly summarizes the historical development of waste water reclamation and describes ways in which waste water may be utilized. The engineering, public health, economic, legal, and aesthetic problems encountered in waste water reclamation are discussed.

219 M USE OF SOIL LYSIMETERS IN WASTE WATER RECLAMATION STUDIES
Orlob, Gerald T., and Robert G. Butler
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 82(SA3): 1002, June 1956.

Descriptors: Spray disposal, Surveys, Costs, California.

Soil lysimeters were found to provide a convenient and inexpensive means of studying the fundamental behavior of soils under various conditions of water and sewage spreading. They were shown to be of value in estimating the performance of soils under large-scale spreading operations.

The lysimeters were constructed of corrugated iron pipe sections, three feet in diameter and five feet deep. Twenty Lysimeters were used to study the characteristics of five agricultural soils under various loading conditions with fresh water and clarified effluent from primary-treated municipal sewage.

Data are presented on infiltration rate versus time curves. The methods and results are discussed.

220 M UNITED STATES SEWAGE TREATMENT PRACTICES DURING THE EARLY TWENTIETH CENTURY
Porges, R.
Sewage Ind. Wastes, 29: 1321-1332, December 1957.

Descriptors: Surveys, Wastewater treatment, United States, Septic tanks, Activated sludge effluents.

The author presents an analysis of an early unpublished sewage treatment facility inventory. The data reported actually covers two inventories, one reporting facilities installed prior to 1911 and the other with an effective survey date of 1916. Several pertinent facts of interest were noted by the author. These early observers noted that installations limited to septic tanks were operating inefficiently. The growth of sewage systems from 1860 to 1955 is depicted in a figure and shows the rapid increase following development of the activated sludge process in the early 1900's. It is interesting to note that land application approaches amounted to about 8 percent of the total number of plants for both the 1910 and 1916 surveys and that intermittent sand filters were the most common type of secondary treatment.

221 I ADAPTATION OF TREATED SEWAGE FOR INDUSTRIAL USE
Powell, Sheppard T.
Ind. Eng. Chem., 48: 2168-2171, 1956.

Descriptors: California, Water reuse, Activated sludge effluents.

The treatment of liquid wastes for further use has passed the experimental stage and offers a practical solution for many industrial water problems.

Intelligent appraisal and engineering principles can solve the problems of collection, treatment, and reuse of sewage. The value of this type of water conservation should be publicized at both local and national levels, especially with regard to its adaptability and means for processing.

The California State Water Pollution Control Board has stated:

> *"There appears to be no physical reason for treating waste water as being fundamentally different from any other water source. The uses to which it can be put are the same, and the precautions taken before using it are the same."*

222 M AGRICULTURAL USAGE OF SEWAGE OF THE TOWN OF ZORY
Prochal, P.
Zesz. Nauk. Wyzsz. Szk. Roln. (Pol.), 5: 165-183, 1958. Chem. Abstr., 53: 8483, 1959.

Descriptors: Wastewater disposal, Fish farming, Recycling nutrients, Plant growth, Europe.

The nitrogen content of this sewage is 154 mg/l; phosphorous content is 18 mg/l; and potassium content is 52 mg/l. There is only a small amount of toxic sulfides, but a large amount of toxic lipids. If used as a fertilizer this sewage should increase meadow crop yields fivefold, field crops should be doubled, and the yield of fish from ponds should be increased fourfold.

223 M SEWAGE--A RAW WATER SUPPLY
Rawn, A. M., and F. R. Bowerman
Water Sewage Works, 103: 463-467, 1956.

Descriptors: Water reuse, Costs, Arizona, Design data.

The authors recommend planned water reclamation from sewage by establishing water treatment plants. Several historical examples are cited: Grand Canyon, Arizona, Golden Gate Park, and Baltimore. Design factors are discussed, and comparative costs are given.

224 M INVESTIGATIONS ON THE SPREAD OF BACTERIA CAUSED BY IRRIGATION WITH WASTE WATER
Reploh, H., and M. Handloser
Arch. Hyg. (Berlin), 141: 632-644, 1957. Pub. Health Eng. Abstr., 39: S: 54.

Descriptors: Sprinkler irrigation, Buffer zones, Forage crops, Aerosols, Germany.

High values for the spread of bacteria as given in the literature cannot be obtained when the present customary types of sprinkling equipment are employed. But it has to be assumed that, at high wind velocity, very small droplets containing bacteria are spread considerably beyond the proper zone of action. When the use of sprinkling equipment is projected, this must be taken into consideration and strips of land of sufficient size provided for protection from spread by wind. Probably, the zone spread can be safely lessened by planting hedges for protection from the wind.

225 S UTILIZATION OF SEWAGE SLUDGE FOR THE PRODUCTION OF TOPSOIL

Scanlon, A. J.
Sewage Ind. Wastes, 29: 944-950, August 1957.

Descriptors: Odor, New York, Recycling nutrients, Design data.

In New York City, the idea of recovering organic sewage solids and returning them to the soil as fertilizer has been advocated since the early screening plants were built in Brooklyn and Queens. No significant progress was made in this direction until 1935, when the practice of separate sludge digestion was established at the Coney Island sewage treatment plant. Digestion not only produces an odorless sludge acceptable as a fertilizer or soil conditioner, but also yields a valuable product in the form of methane gas which is used for heat and power.

226 M EFFLUENT GROWS CROPS ON "SEWER FARM"

Scott, T. M.
Wastes Eng., 30: 486-489, September 1959.

Descriptors: Bakersfield, California, Forage crops, Sprinkler irrigation, Rates of application, Primary effluent.

In Bakersfield, California, a 2,500-acre farm is used as the final disposal area for about 8,480-acre feet of effluent per year. Only primary treatment is provided and as a result, only crops not for human consumption such as cotton and cattle fodder are grown. It is felt that the present farm could absorb 17,000-acre feet a year and that secondary treatment would allow food crops to be grown.

227 M IRRIGATION WITH SEWAGE EFFLUENTS
Skulte, Bernard P.
Sewage Ind. Wastes, 28: 36-43, January 1956.

Descriptors: Wastewater disposal, Sprinkler irrigation, Planning, Europe.

The primary objective of early sewer farms was simply disposal with the result that often too much sewage was used on too little land. New methods of using sewage for planned irrigation increase its value in water-short areas. The author urges more emphasis on pilot plant and research installations to study irrigation with sewage effluents and industrial wastes. Many of the outstanding problems could thus be solved.

228 I EFFLUENT DISPOSAL BY IRRIGATION
Simmers, R. M.
New Zealand Eng. (Wellington), 15: 410-413, 1960.

Descriptors: Anaerobic digestion, Food processing wastes, Forage crops, New Zealand.

The author describes a scheme whereby slaughterhouse wastes are disposed of by irrigation over grazing land. Fodder growth has been extraordinary, being capable of grazing over 20 sheep per acre. No nuisance has been apparent, and no stock troubles have been encountered in grazing cattle or adult sheep on the area.

In suitable localities, irrigation with clarified effluent from anaerobic digesters should be considered. The readily available nitrogen would be higher, and the risk of stale areas from ponding would be reduced.

229 M STREAM POLLUTION--SIGNIFICANCE OF MINERALS IN WASTE-WATER
Stone, Ralph, and C. Merrell, Jr.
Sewage Ind. Wastes, 30: 928-936, July 1958.

Descriptors: Water reuse, Sprinkler irrigation, Heavy metals, Groundwater recharge, Dissolved solids.

Mineral quality is the controlling factor in employing reclaimed wastewater for many purposes. A normal sewage effluent will develop additional mineralization of 100 to 450 ppm. measured as total dissolved solids in one municipal water-use cycle. Mineral pickup greater than 600 ppm. is probably attributable to tidal water or oil field brines. Industrial wastes may contain toxic constituents such as boron or heavy metals. Treated sewage effluent can provide water of reasonable mineral quality, suitable for irrigation of grasses or other vegetation, industrial water supply, and groundwater recharge. Analyses of waste water indicate that toxic materials, heavy metals, and other minerals can be suitably controlled within a sewage system.

230 S LAND IN SEWAGE PURIFICATION
Stone, A. R.
J. Inst. Sewage Purif. (London), Pt.4: 417-424, 1960.

Descriptors: England, Sludge disposal, Recycling nutrients.

The author cites British experience with land disposal and discusses reasons behind several monumental failures. The agricultural disposal of sludge is dealt with in some detail and is recommended as an integral part of land disposal of sewage. Experience at Nottingham is described in detail, where sludge disposal and irrigation with effluent have been studied.

231 M SOIL IMPROVEMENT SOCIETY ORGANIZED TO PRODUCE AND TO UTILIZE COMPOST OF REFUSE
Tietjen, Cord, and Hans Joachim Banse
Calif. Vector Views, 7: 1-7, January 1960.

Descriptors: Wastewater disposal, Sludge disposal, Water reuse, Germany.

The article demonstrates how cooperation between people who produce wastes and those who can use the wastes leads to increased efficiency in waste disposal.

232 M ANNOTATED BIBLIOGRAPHY ON ARTIFICIAL RECHARGE OF GROUNDWATER THROUGH 1954
Todd, David K.
U.S. Geol. Surv. Water-Supply Pap. 1477, 1959. 115 p.

Descriptors: Groundwater recharge, Wastewater disposal, Water reuse, Bibliographies, United States.

The author lists the various methods used in artificial recharge operations and considers the factors that are important in the selection of the method. The bibliography lists the literature pertaining to artificial recharge of *groundwater up to and including the year 1954. Each reference is abstracted, authors are listed alphabetically, and an index based on subject and locality is included. The bibliography section covers pages 5 through 107 of the report.*

233 M ORGANIZING A SEWAGE EFFLUENT UTILIZATION PROJECT
Travis, Paul W.
Pub. Works, 91: 119-120, September 1960.

Descriptors: Primary effluent, Deep percolation, Salinity, California, Planning.

Southern California's Talbert Water District uses the effluent from the Orange County Sanitary District's primary sedimentation plant for crop irrigation under approval of health officials. Preceding the full-scale installation, irrigation of a model farm of several acres was studied for three years to observe effects on local soil and on subsoil percolation.

Strict regulations were adopted in regard to reservoir management, pumping from the treatment plant outfall main, and salt accumulation in the soil. Major points covered in agreements between supplier and user are discussed. The farmer pays $6 per acre-foot for the effluent pumped to his highest land. Some 2,800 acres are irrigated in the system. The farm advisor believes that crops can be doubled with the incidental application of the added nutrients.

234 M WATER RECLAMATION EXPERIMENTS AT HYPERION
Vander Goot, H. A.
Sewage Ind. Wastes, 29: 1139-1144, October 1957.

Descriptors: Groundwater recharge, California, Costs, Spreading basins, Injection wells.

The use of ground water in Los Angeles has resulted in salt water intrusion. Because of this and the demand for more water in the future, measures to recharge the groundwater are necessary. One such measure is the use of sewage effluent in spreading basins and recharge wells. It was found that suitable recharging water was obtainable from spreading basins, although cost comparisons with other sources of water have not been made.

235 S DO'S and DON'TS OF USING SLUDGE FOR SOIL CONDITIONING AND FERTILIZING
Van Kleeck, W.
Wastes Eng., 29: 256-257, 274, May 1958.

Descriptors: Public health regulations, Sludge disposal, Anaerobic digestion, Plant response, Connecticut.

Various methods of sludge disposal are discussed with emphasis on use as a soil conditioner. The characteristics of both raw and various forms of digested sludge which affect the soil and crops are pointed out. As a guide to the attitude of public health authorities on the use of sludge on soils, the author quotes the policy of the Connecticut State Department of Health.

236 M QUALITY OF IRRIGATION WATER
Wadleigh, C. H., L. V. Wilcox, and M. H. Gallatin
J. Soil Water Conserv., 11: 31-33, 1956.

Descriptors: Water quality data, Water reuse, Soil chemical properties.

The quality of irrigation water is determined by the kinds of dissolved salts, the relative proportions of certain ions, and the total concentration. This paper is concerned with evaluation of water quality, as affected by naturally occurring solutes.

237 I THE USE OF SPRINKLER IRRIGATION SYSTEMS FOR WASTE DISPOSAL
Werly, E. F.
Irrigation Eng. Maint., 8: 1: 21-27, 1958.

Descriptors: Wastewater disposal, Economic feasibility, Sprinkler irrigation, Design data.

Discussion covers the problems, requirements, and considerations given for the development of an efficient and economic sprinkler system for waste disposal.

238 M MODIFICATIONS OF POLLUTED WATERS RESULTING FROM PERCOLATION IN SOIL
Wheatland, A. B., and B. J. Borne
Water Pollution Research Lab., Stevenage, England, CEBEDEAU (Belgium), 49: 225-34, 1960.

Descriptors: Deep percolation, Ion exchange, Nitrification, Heavy metals.

Tests conducted with a sewage effluent and water from the river Trent indicate that the percolation of these liquids through the soil removes NH_3 by cationic exchange. The removal of NH_3 depends on the nitrification of the NH_3 already adsorbed. At normal temperatures during most of the year, most of the NH_3 is removed if an intermittent system of distribution (e.g., by 12-hr cycles) is employed. It is important not to distribute water containing more NH_3 than the superficial bed can adsorb and to allow sufficient time between distributions for the penetration of atmospheric 0 and for the adsorbed NH_3 to be oxidized. In practice the rate of percolation will be determined both by the surface and by the perimeter of the area of dispersion, and the rate per unit of surface will vary inversely with the perimeter. Concentrations of Cu, Ni, Cr, Mn, Zn, and Pb in the percolate were much lower than in the water distributed. The proportion of bacteria removed varied between 81 percent and 96.5 percent within the test area considered.

239 M AUGMENTING WATER SUPPLY SOURCES THROUGH AGRICULTURAL UTILIZATION OF MUNICIPAL SEWAGE

Wierzbicki, Jan
Gaz Woda Tech. Sanit. (Warsaw), 31: 17, 1957. Abstr., Sewage Ind. Wastes, 29: 1096, September 1957.

Descriptors: Groundwater recharge, Poland, Reviews.

The author reviews the experience of the town of Bielefeld in augmenting its groundwater resources through the utilization of municipal sewage for surface irrigation. Following the sewage utilization program the groundwater tables in the area rose, and 620 hectares of formerly nonutilizable land have been converted into meadows, pasture, and plowed land.

240 M AGRICULTURAL UTILIZATION OF SEWAGE WATERS

Wierzbicki, Jan
Soils Fert., 19: 2096, 1956. Chem. Abstr., 52: 15806, 1958.

Descriptors: Forage crops, Water reuse, Flood irrigation, Grain crops.

Sewage water contains 80 kg/1,000 cu.m. of N, 20 of P_2O_5, and 60 of K_2O. Irrigation with sewage waters increased the yields of hay by 300 to 400 percent, cereals by 20 to 50 percent, and root crops by 100 percent; and it increased the protein content in hay from 6 to 17 percent.

241 M A REPORT OF PRESENT ACTIVITIES IN ISRAEL
Yehuda, Peter
Water Sewage Works, 105:493, 1958.

Descriptors: Israel, Spreading basins, Flood irrigation, Forage crops, Groundwater recharge.

The primary effluent from a number of sewage treatment plants is pumped to a 55-acre sand dune at the rate of 2,000 to 2,500 gpd/acre. Sandy loam underlies the dune at depths of 13 to 23 feet. The annual rainfall averages 20 inches. Cattle fodder is grown, and a good humus layer formed during the first year of cultivation, helping to stabilize the shifting sands.

A natural depression is used as an experimental percolation area. Sewage effluent is applied at the rate of 85,000 to 100,000 gpd/acre, ten times the agricultural irrigation rate. This raises the fresh water table and prevents salt water intrusion.

SECTION V

ABSTRACTS 1961 THRU 1965

242 S WASTES DISTRIBUTED TO LAND
Anonymous
Compost Sci., 3(1): 14, March 1962.

Descriptors: Sludge disposal, Soil types, Public health regulations.

A member of the Board of Health reports that digested liquid sludge, excess whey, and spent sulfite liquor are the organic wastes that may be deposited directly on the land.

243 S ADVANCES IN SLUDGE DISPOSAL IN THE PERIOD FROM OCTOBER 1 1954 TO FEBRUARY 1, 1960
Anonymous
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 88(SA2): 13-51, March 1962.

Descriptors: Sludge disposal, Soil types, Soil chemical properties, Costs, Reviews.

This report relates to matters of sludge disposal: digestion; gas utilization; elutrition; vacuum filtration; drying; incineration; use as fertilizer and soil conditioner; disposal at sea; by-products; and special processes. Continued efforts are being made to reduce the operational problems and costs of this phase of sewage treatment.

244 S SLUDGE TO SEA OR LAND (Management Memoranda)
Anonymous
Water Waste Treat. J. (London), 8(5): 240-242, 1961.

Descriptors: Sludge disposal, Costs.

This article compares costs of ocean disposals.

245 I EFFLUENT TREATMENT BY SPRAY IRRIGATION

Anonymous
Water Waste Treat. J. (London), 10: 105, 1964.

Descriptors: Water quality data, Soil types, Oxidation lagoons, New Zealand, Sprinkler irrigation.

Spray irrigation is employed in New Zealand as an effective and economical method of treatment and disposal of a variety of trade wastes. Initial BOD values are in some cases very high. The BOD values of drainage from the fields and of nearby rivers receiving the drainage are closely checked and found to be satisfactory. Up to 65,000 gpd are being disposed of in this way, using land areas of 3 to 60 acres. The technique is successful on a variety of soil types and in locations near rivers. In most cases, the effluent is used on grassland, which is exploited by grazing livestock. Lagooning may be employed as a means of reducing pollution before spraying. Several specific examples are cited with details of operation.

246 M EXPERIENCE OF COMPREHENSIVE SANITARY AND MICROBIOLOGICAL EVALUATION OF SEWAGE IRRIGATION FIELDS IN THE SUBURBS OF LENINGRAD

Adel'son, L. I., et al.
Hyg. Sanit. (USSR), 30(10-12): 129-131, 1965.

Descriptors: Vegetable crops, Raw sewage, Soil types, Soviet Union.

A total of 17 samples of sewage and 27 samples of drainage water, 131 samples of soils and 21 series of samples of vegetables, principally cabbage, was used in this experiment. A total of 1,774 analyses was made. Besides cabbage, cauliflower and potatoes were also used. This article dealt with the following three areas:

1. *The degree of efficiency of sewage purification in the SIF (sewage irrigation fields).*
2. *The degree of contamination of the soil in SIF and whether it undergoes spontaneous decontamination fast enough.*
3. *The possibility of using those vegetables grown in SIF.*

247 M WASTE TREATMENT FOR GROUNDWATER RECHARGE

Amramy, A.

J. Water Pollut. Contr. Fed., 36: 296-298, March 1964.

Descriptors: Groundwater recharge, Israel, Oxidation lagoons, Spreading basins, Groundwater contamination.

A study was made in Israel to reclaim wastewater from the Tel-Aviv Metropolitan area of 1 million population. Raw sewage is treated in a lagoon prior to spreading in prepared basins (3-4 acre plots) situated in sand dune areas. Some conclusions are: (1) 56 cm/day average of effluent were infiltrated in one of the spreading basins in 700 days, (2) initial infiltration rates as high as 522 cm/day were observed, (3) the terminal infiltration rate in some operating cycles decreased as low as 2 cm/day, (4) a relatively long resting period resulted in restoring the original infiltration rates, (5) very long wetting periods followed by short (5 to 11 days) resting periods give rise to residual clogging cycle to cycle, and (6) 1: 2 ratio of wetting to resting is required to establish a long operation without clogging taking place and no progressive buildup of organic matter. Organic matter tended to accumulate at the top layer of 0 to 10 cm. Black sand layers appear at the subsoil but are believed not to cause clogging. Intermittent application restores the infiltrative capacity of the dune sand.

248 M MICROBIOLOGY OF RECLAIMED WATER FROM SEWAGE FOR RECREATIONAL USE

Askey, J. B., R. F. Bott, R. E. Leach, and B. L. England

Amer. J. Pub. Health, 55: 453-462, February 1965.

Descriptors: Coliforms, Viruses, Oxidation lagoons, Raw sewage, Santee, California.

As part of a continuing research program at the Santee Sewage Treatment Plant, intensive bacteriologic and virologic tests have been performed on specimens from seven sampling points. Bacteriologic determinations indicate that it is possible to create a lake from reclaimed water that has coliform counts within the limits allowed for conventional origin. Virological tests completed to date on samples of raw sewage, primary settling effluent, and activated sludge effluent have been 100 percent positive, yielding 13 distinctive viruses. The percent of samples positive after approximately 30 days detention in an oxidation pond dropped to 25, and the recreational lake samples have been consistently negative for virus.

249 M TRANSFORMATIONS IN INFILTRATION PONDS AND IN THE SOIL LAYERS IMMEDIATELY UNDERNEATH
Baars, J. K.
In: Principles and Applications in Aquatic Microbiology, Heukelekian, H., and N. C. Dondero (ed.), New York, John Wiley & Sons, Inc., 1964. p. 344-365.

Descriptors: Groundwater recharge, Netherlands, Deep percolation, Wastewater treatment, Soil chemical properties.

In the Netherlands, water from the Rhine River is being used to recharge the groundwater in the dune area. Three systems are described and the chemical and biological transformations that take place during infiltration are analyzed.

A comparison is made between two permanent or continuous infiltration operations and an intermittent operation. The continuous operations employ pretreatment by rapid sand filtration and chlorination and use infiltration rates of 10 and 40 centimeters per day. The intermittent system has no pretreatment and uses a rate of 10 cm per day. Improved removal of organic matter is noted for the intermittent system. The intermittent system at Leyden has been operating since 1940 and each year, when infiltration is begun, the same infiltration rate is achieved without artificial cleaning of the ponds.

250 M BACTERIAL CONTAMINATION OF SOIL AND VEGETABLES ON FIELDS AFTER SEASONAL SEWAGE IRRIGATION IN THE SOUTHERN UKRAINE
Babov, D. M.
Gig. Sanit. (Moscow), 27: 37-41, November 1962.

Descriptors: Soviet Union, Vegetable crops, Pathogenic bacteria, Flood irrigation, Public health regulations.

The investigation showed that the use of sewage for irrigating agricultural fields in the Southern Ukraine is accompanied by contamination of soil and vegetables with intestinal bacteria. However, as the result of energetic self-purification processes, the ripe vegetables harvested in these fields do not differ in level of bacterial contamination from those in the market. In case of serious infringements of the irrigation regimen and of the time fixed for cessation of irrigation before harvest, live pathogenic bacteria may be found on vegetables. An almost complete absence of intestinal bacteria on corn silage points to the advantages of agricultural sewage irrigation of fields for the growing of corn.

251 S LIQUID SLUDGE DISPOSAL AT MIAMI, FLORIDA
Backmeyer, D. P.
Compost Sci., 6(2): 10-11, Summer 1965.

Descriptors: Florida, Operation and maintenance, Rates of application, Sludge disposal.

All digested sludge at Miami plant is now successfully applied in liquid form, eliminating expense of dewatering operation.

252 M AIR FORCE ACADEMY SEWAGE TREATMENT PLANT DESIGNED FOR EFFLUENT REUSE
Bauer, J. H.
Pub. Works, 92: 120-122, June 1961.

Descriptors: Design data, Planning, Water reuse, Colorado.

Because of limited rainfall and the planned landscaping of the site, the need for a large amount of irrigation water was foreseen. It was planned to utilize the sewage plant effluent to meet this need. Only the excess effluent was to be released to the creek.

Engineering design data and operating results are given.

253 S COMBINED DISPOSAL OF SEWAGE SLUDGE AND REFUSE
Black, Ralph J.
Compost Sci., 3(4): 16-17, December 1962.

Descriptors: Sludge disposal, Raw sewage, Economic feasibility, United States.

Combined treatment of refuse and sewage sludge is one approach to solid waste disposal problem that should receive serious attention.

254 M UTILIZATION OF WATER AND IRRIGATION IN ISRAEL
Blaney, H. F.
Amer. Soc. Civil Eng., J. Irrigation Drainage Div., 88(IR2): 55-65, June 1962.

Descriptors: Israel, Water reuse, Economic feasibility, Flood irrigation.

The needs for, and potentials of, reuse of sewage as irrigation water in Israel is discussed. It is stated that the state of Israel's future and the economic welfare of its agriculture are more dependent on the supply and quality of irrigation water than any other single resource. The total water resources are estimated at 2,000 million cu.m., of which 1,500 million cu.m. will be allocated to irrigation. Return flow from sewage and irrigation is estimated at 165 million cu.m.

255 I IRRIGATION AND LAND DISPOSAL OF PULP MILL EFFLUENTS
Blosser, Russell O., and Eben L. Owens.
Water Sewage Works, 111: 424-432, 1964.

Descriptors: Forage crops, Rates of application, Salinity, Pulp and paper wastes.

Interest in land disposal of many industrial wastes has increased in recent years. For the many industrial wastes that are unsuitable for agricultural irrigation purposes, the primary concern is disposal. Paper mill effluents fall in this category, usually having a high sulfite content and low pH.

Laboratory studies dealt with changes in effluent characteristics, in soil characteristics, and in cover vegetation conditions when a wide variety of effluents were applied to the soil in simulated irrigation practice. Grasses were used for cover vegetation. Alta fescue was found to have high moisture resistance and reasonably high salt tolerance with an extensive root system. Results of the study are discussed.

256 M METHODS OF TREATING AGRICULTURAL LAND--A GOOD METHOD FOR THE TREATMENT AND APPLICATION OF SEWAGE
Blumel, F.
Wasser Abwasser (Leipzig), 35-45, 1965.

Descriptors: Rates of application, Raw sewage, Microbial degradation, Agriculture.

Existing methods for use of sewage in agriculture and plans for its use in modern farming and soil improvement are discussed, and the author reviews the application of sewage on land without preliminary treatment, after mechanical treatment, and after biological treatment, and compares these methods with those used abroad. Special reference is made to the use of sewage effluents and trade wastewaters for irrigation.

257 M CHEMICAL CHANGES IN SOIL IRRIGATED WITH MUNICIPAL SEWAGE

Bocko, J., and L. Szerszen
Zesz. Nauk. Wyzsz. Szk. Roln. Wroclawiu Melior. (Wroclaw, Pol.), 7: 71-82, 1962.

Descriptors: Raw sewage, Soil chemical properties, Soil physical properties, Rates of application, Poland.

No significant changes were observed in humus and nutrient content in the soil after sprinkling with sewage at low rates of application; but alkalinity increased slightly, especially in the deeper soil layers. In filtration fields, because of the high sewage load, organic substances accumulated in the soil and the sorption capacity increased. A constant supply of sewage resulted in a decrease in pH. No accumulation of alkalis occurred in light-soil filtration fields.

258 M DISPLACEMENT OF IRON IN SOIL IRRIGATED WITH SEWAGE

Bocko, J.
Zesz. Nauk. Wyzsz. Szk. Roln. Wroclawiu Melior. (Wroclaw, Pol.), 10: 209-217. Abstr., Soils Fert., 29: 82(527), 1966.

Descriptors: Anaerobic conditions, Soil chemical properties, Deep percolation, Soil physical properties, Poland.

Decomposition of sewage in soil causes oxygen deficit, resulting in a reduction of Fe^{3+} and leaching of Fe^{2+} to the lower horizons. The displaced Fe accumulates in the lower horizons, forming an impermeable layer inhibiting water percolation into the drains.

259 M QUALITY ASPECTS OF WASTE WATER RECLAMATION

Bonderson, Paul R.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 90(SA5): 1-8, 1964.

Descriptors: Water quality standards, Groundwater recharge, California.

The author examines the effects of reclamation projects on the water resources of an area. The subjects considered are: (1) trends in wastewater reclamation; (2) modes of augmenting water resources by such reclamation; and (3) quality aspects associated with such augmentation.

260 M WATER QUALITY DEPRECIATION BY MUNICIPAL USE
Bunch, Robert L., and M. B. Ettinger
J. Water Pollut. Contr. Fed., 36: 1411-1414, November 1964.

Descriptors: Wastewater disposal, Organic loading, Water quality data, Water reuse.

Future reuse of sewage effluents will not be a question of economics, but one of necessity. By 1980, 75 percent of the population will reside in metropolitan areas, and six-time reuse can be anticipated. The study provides information on the organic and inorganic load contributed by one cycle for five cities. The analytical data are tabulated. Generalizations are unwise without considering the loading on the specific treatment plant and the contributions of industrial wastes. Orders of magnitude are indicated that would be helpful in making rough calculations for planning wastewater utilization.

261 I INDUSTRIAL REUSE OF WATER: AN OPPORTUNITY FOR THE WEST
Cannon, Daniel W.
Water Sewage Works, 111: 250-254, 1964.

Descriptors: Water reuse, Reviews.

The author discusses the reuse of water within the petroleum and steel industries. He briefly refers to industrial use of water which has been previously used for municipal purposes; to agricultural use of water previously used for industrial purposes; and to municipal use of water previously used for industrial purposes.

262 M PASTURE FERTILIZATION WITH SEWAGE EFFLUENT IRRIGATION
Chapman, C. J.
Compost Sci., 3(3): 25, September 1962.

Descriptors: Wisconsin, Flood irrigation, Crop response, Forage crops, Raw sewage.

Wisconsin tests show crop yields greatly increased by irrigation with waters carrying effluent from city sewage disposal system.

263 M SEWAGE TREATMENT PLANT EFFLUENT FOR WATER REUSE

Cecil, Lawrence K.
Water Sewage Works, 111: 421-423, 1964.

Descriptors: Oklahoma, Nutrient removal, Detergents, Wastewater treatment, Water reuse.

The cost of sewage treatment may be partially recovered by selling the treated effluent to industry for reuse. The merit of this practice will depend on how well the effluent quality meets the needs of the prospective user as well as how it compares with other sources of water.

Additional treatment processes may be necessary to reduce concentrations of undesirable components such as ammonia, phosphates, calcium, and foam-producing organic compounds. The extent of additional treatment is limited by cost and is practical only where overall cost is less than that for an alternate source.

Refineries at Duncan and Enid, Oklahoma, and a zinc smelter in a desert area found that effluents from nearby sewage treatment plants provided a better and less variable quality of water than was available from other sources.

264 S EXPERIMENTS IN EAST HERTFORDSHIRE ON THE USE OF LIQUID DIGESTED SLUDGE AS A MANURE FOR CERTAIN FARM CROPS

Coker, E. G.
In: Proc. Inst. Sewage Purif. (London), 1965. p. 419-426.

Descriptors: Sludge disposal, Crop response, Hertfordshire, England, Rates of application, Heavy metals.

The author summarizes the results of studies carried out by the Hertfordshire Institute of Agriculture on the use of liquid digested sludge as a fertilizer for various crops. In all the trials the sludge was applied thinly to the soil. It was found that the liquid sludge gave an increase in dry-matter content similar to that produced by an equivalent amount of nitrogenous fertilizer and grass responded much more rapidly to application of the liquid sludge than to air-dried sludge, suggesting that the nutrients in liquid sludge are more rapidly available. In discussion, the possible risks of transmitting pathogens to grazing stock and the effect of toxic metal ions in the sludge were considered.

265 M ONCE-USED MUNICIPAL WATER AS INDUSTRIAL SUPPLY: IN RETROSPECT AND PROSPECT

Connell, C. H., and M. C. Forbes
Water Sewage Treat., 3: 397-400, 1964.

Descriptors: Costs, Water quality data, Reviews, Water reuse.

The authors state that the total amount of used municipal water is approaching 20 bgd and that over 40 percent of it may in time be used for industrial water. In reviewing direct industrial utilization of sewage effluents, the authors briefly discuss the availability and costs relevant to water quality.

266 M IRRIGATION POTENTIAL OF SEWAGE EFFLUENTS

Cormack. R. M. M.
J. Inst. Sewage Purif. (London), Pt. 3: 256-257, 1964.

Descriptors: South Africa, Flood irrigation, Economic feasibility.

Scarcity of water in Southern Africa makes the use of sewage effluent for irrigation attractive and worthy of consideration. Whether reclaimed water is used for one purpose or another, matters little in the final analysis. Every gallon of reclaimed water represents a saving from other sources of supply.

The use of reclaimed sewage effluent for agricultural and horticultural purposes represents not only sound water economy but also good fertilizer economy. It is estimated that the fertilizer value in sewage effluent from the Aisleby Works at Bulawayo is about seven cents per 1,000 gallons.

267 M EFFECT OF CITY SEWAGE EFFLUENT ON THE YIELD AND QUALITY OF GRAIN FROM BARLEY, OATS, AND WHEAT

Day, A. D., et al.
Agron. J., 54(2): 133-135, March-April 1962.

Descriptors: Arizona, Crop response, Flood irrigation, Grain crops.

Barley, oats and wheat all showed superior growth when irrigated with sewage effluent, even when compared to crops fertilized at rates equal to the nutrient concentrations in the effluent. This test was run for two years at Cortaro, Arizona.

268 M STUDIES ON THE USE OF SEWAGE EFFLUENT FOR IRRIGATION OF TRUCK CROPS
Dunlop S. G., and W. L. Wang
J. Milk Food Technol., 24: 44-47, February 1961.

Descriptors: Human diseases, Furrow irrigation, Fruit crops.

The authors report on studies which were designed to assess the public health hazards associated with the use of sewage effluent for irrigation under field conditions. These studies concluded that no significant contamination results from the use of chlorinated effluent diluted in streams and subsequently used in furrow irrigation.

269 M PLANT EFFLUENT SOLD FOR IRRIGATION WATER
Dye, E. O.
Wastes Eng., 32: 636, 1961.

Descriptors: Tucson, Arizona, Groundwater recharge, Recycling nutrients, Costs.

Operational expenditures are defrayed by 40 percent through sale of the effluent, digested sludge, and digester gas from the activated sludge plant at Tucson, Arizona. Also, a portion of the water applied for irrigation serves to recharge groundwater, thus, replenishing to some extent the principal water resource in this arid area.

270 M THE EFFECT OF IRRIGATION WITH TOWN SEWAGE ON VARIOUSLY FERTILIZED MANGEL-WURZEL AND SUNFLOWER GROWN FOR FODDER
Dziezyc, J., and M. Trybala
Zesz. Nauk. Wyzsz. Szk. Roln. Wroclawiu Melior. (Wroclaw, Pol.), 8: 43-52, 1963.

Descriptors: Raw sewage, Flood irrigation, Rates of application, Poland, Plant growth.

Application of 300-600 mm sewage water, especially when combined with mineral NPK, increased size of foliage and root diameter in mangold. Growth of sunflower was increased by NPK and depressed by PK.

271 S UTILIZATION AND DISPOSAL OF SEWAGE SLUDGE
Eberhardt, H., and H. Ermer
Staedteh. (Hamburg), 13: 175-179, 1962.

Descriptors: Sludge disposal, Economic feasibility, Soil types, Rates of application.

The authors discuss the various methods of sewage sludge utilization or disposal and the conditions under which each can be applied. Methods are described for the agricultural use of wet or dry sludge, for drying and composting, and for disposal on land or at sea. Methods for incinerating sludge and for producing gas are also discussed.

272 M ION EXCHANGE FOR RECLAMATION OF REUSABLE SUPPLIES
Eliassen, Rolf, Bruce M. Wyckoff, and Charles D. Tonkin
J. Amer. Water Works Ass., 57: 1113-1122, September 1965.

Descriptors: California, Ion exchange, Economic feasibility, Phosphorus removal, Denitrification.

The authors describe experimental studies on the removal of phosphates and nitrates from sewage plant effluents by an ion-exchange process. The laboratory work was performed at Stanford University, and the pilot plant work was done in cooperation with the city of Palo Alto, California. The work included an economic study of the ion-exchange process. The removal of phosphates and nitrates is desirable to prevent the growth of algae and to permit maximum reuse of this large potential water resource.

273 I FOOD PROCESSING WASTE DISPOSAL
Fisk, William W.
Water Sewage Works, 111: 417-420, 1964.

Descriptors: Sprinkler irrigation, Suspended solids, Michigan, Silviculture.

Two methods of waste disposal are employed at Gerber Company plants. At Asheville, North Carolina, the wastes are ground, solids removed, and used for animal feed. The wastewater is discharged to the French Broad River.

At Fremont, Michigan, spray irrigation is employed. Large solids are removed for animal feed. Wastewater is pumped to a 140-acre site having 50-ft depth of Ottawa Sand. Sprinklers are spaced at 120 ft and deliver

81 gpm over an area 210 ft in diameter. Several cover crops have been grown. Solids accumulation and surface compaction require "subsoiling" the spray area every 2 or 3 years. Test wells 500 ft from the spray area reveal no measurable effect on groundwater level or quality.

274 M WATER REUSE BY DESIGN
Fleming, Rodney R.
Amer. City, 78: 106-108, October 1963.

Descriptors: Greenbelts, Water reuse, Flood irrigation, Southwest U.S., Recreational facilities.

The author reviews the reuse of sewage effluents as practiced in the United States. Large quantities are reclaimed for both industrial and agricultural reuse. Other reuse includes groundwater recharge to prevent salt water intrusion. Over 200 municipal plants in Texas supply effluent for irrigation. Several Arizona and New Mexico cities water golf courses and parks with sewage effluent. Other examples of reuse are cited.

275 I SPRAY IRRIGATION--A POSITIVE APPROACH TO A PERPLEXING PROBLEM
Flower, W. A.
In: Proc. 20th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1965. p. 679-683.

Descriptors: Ohio, Forage crops, Sprinkler irrigation, Rates of application, Groundwater contamination.

The Howard Paper Mills of Urbana, Ohio, was faced with the problem of providing waste treatment for its industrial wastes, and after consideration of several alternatives turned to spray irrigation after experimentation on a small plot using a cover crop of alfalfa. Wastes were applied at a rate of 4 inches per day every six days. Disposing or selling of the crop proved to be a problem due to farmers' fears of toxic materials contained in the plants. Groundwater supplies did not appear to be affected badly by the irrigation.

276 M NUTRIENT REMOVAL BY EFFLUENT SPRAYING
Foster, H. B., Jr., P. C. Ward, and A. A. Prucha
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 91(SA6): 1-12, December 1965.

Descriptors: California, Coliforms, Denitrification, Phosphorus removal, Spray disposal.

Sewage effluent was sprayed on an 80-acre hillside, sparsely forrested with pine. During 1963, over 90 percent of the total phosphate, over 56 percent of the total nitrogen, and over 65 percent of the ABS were removed from the hillside. The following spring, April 1964, removal efficiencies were found to be lower. At this time, the hillside was thoroughly saturated with the melt from ice and snow banks. The hillside was covered with heavy snow during the early months of 1965. Masses of ice had built up around the spray nozzles. Removal efficiencies were lower than at any previous times. Phosphate, total nitrogen, and ABS removals were 17 percent, 36 percent, and 32 percent, respectively. During all periods of study the fecal coliform and enterococcus densities were greatly reduced by the passage over the hillside spray area.

277 S UBER DIE WIRKUNG VON KLARSCHLAMM AUF BODEN UND MIKROORGANISMEN
(THE EFFECT OF SEWAGE SLUDGE ON SOILS AND MICRO-ORGANISMS)
Glathe, H., and A. A. M. Makawi
Z. Pflanzenernaehr. Dueng. Bodenk. (Berlin), 101: 109-121, 1963.

Descriptors: Sludge disposal, Coliforms, Microbial degradation, Soil types, Raw sewage.

In pot experiments with sewage sludge applied to loam and sandy soil, fresh sludge had a superior effect in increasing total counts of microorganisms and cellulose decomposers. Though there was little difference in the effect of autoclaved and ethylene-oxide-sterilized sludge in increasing microbial populations, the former material had the greatest effect in promoting azotobacter. Application of fresh, sterilized, and autoclaved sewage sludge (in this decreasing order of efficiency) increased CO_2 production in soil and promoted the production of NO_3 and NH_4. Fresh sewage contained large numbers of coliform bacteria which rapidly increased in soil for eight days after application and persisted even after thirty days.

278 M IRRIGATION PROCESSES USING RECLAIMED WATER OR EFFLUENT DESCRIBED
Gray, J. Frank
West Texas Today, 45: 18-19, and 23, January 1965.

Descriptors: Lubbock, Texas, Odor, Operation and maintenance, Primary effluent.

Irrigation with sewage effluent at Lubbock, Texas, dates back to the early 1930's. Presently, approximately 2,000 acres are irrigated. The successful operation requires a reservoir storage capacity for about 30 days' output of effluent. The primary difference between irrigation with effluent and general irrigation practice is the requirement of taking all effluent produced.

The chief advantages of irrigation with sewage effluent are regularity of water supply, some fertility value gained, and decreased stream pollution. Some of the disadvantages are odor nuisance, problems created by requirement to take water at all times, more difficulty in keeping farm labor, and over-irrigation which may damage young plants. Data on crops are given.

279 M SURVIVAL OF BACTERIA AND VIRUSES ON VEGETABLE CROPS IRRIGATED WITH INFECTED WATER

Grigor'Eva, L. V., T. G. Gorodetskii, T. G. Omel'Yanets, and L. A. Bogdanenko

Hyg. Sanit. (USSR), 30(10-12): 357-361, 1965.

Descriptors: Pathogenic bacteria, Vegetable crops, Sprinkler irrigation, Surveys, Soviet Union.

Investigates the survival of the pathogenic bacteria of the coli group, Coxsackie viruses of Group A, Escherichia coli, and bacteriophages on the leaves and fruits of plants irrigated with infected water. The plants were grown in a laboratory condition but with natural simulation. At different stages of vegetation period the plants were sprinkled with sewage water with a low coli titer (10-8--10-15) or with water which was additionally contaminated with coli bacteriophage. Survival times of enteroviruses and pathogenic bacteria of E. coli family is compared. The survival time depends on several factors, such as the species of plants, the conditions and length of the vegetation period, the past of the plants investigated (whether leaves or fruit), the species and strain of the microorganism and its initial concentration. Three vegetable species were investigated and their conditions for the survival of bacteria and viruses were discussed. The least favorable conditions for the survival of bacteria and viruses were offered by cabbage leaves and the most favorable by tomato leaves.

280 M USE OF SEWAGE EFFLUENT FOR PRODUCTION OF AGRICULTURAL CROPS

Harvey, C., and R. Cantrell

Texas Water Development Board, Austin, Report 9, December 1965. 8 p.

Descriptors: Texas, Surveys, Costs, Flood irrigation, Plant growth.

The report summarizes the results of a 1965 Texas survey on agricultural use of sewage effluent. Discussed are the suitability and cost of effluent for crop production as well as crops and acreage irrigated. The authors state that "crop irrigation with effluent can contribute to the economy of the area and solve satisfactorily the sewage disposal problem."

281 M SEWAGE RECLAIMED FOR IRRIGATION IN ISRAEL FARM OXIDATION PONDS
Hershkovitz, S. Z., and A. Feinmesser
Wastes Eng., 33: 405 and 416, September 1962.

Descriptors: Israel, Flood irrigation, Coliforms, Oxidation lagoons.

Studies of 36 oxidation ponds showed a marked reduction of coliforms and BOD in sewage previously treated by primary processes.

282 M IRRIGATED LANDS OF THE WORLD
Highsmith, Richard M., Jr.
Geogr. Review, 55: 382-389, 1965.

Descriptors: Surveys, Reviews, United States, Sprinkler irrigation, Flood irrigation.

A comprehensive review of the areas of the world where irrigation agriculture is practiced. Data were collected from several sources, and total irrigated acres for each country are presented in tabular form. A world map is included, showing the geographical location of irrigated areas.

The impact of irrigation on agriculture is realized when the total irrigated acres are reviewed. In 1961, approximately 37.7 million acres were irrigated in the United States. World totals were estimated to be something over 431 million acres.

283 M STATUS OF LAND TREATMENT FOR LIQUID WASTE--FUNCTIONAL DESIGN
Hill, R. D., T. W. Bendixen, and G. G. Robeck
Presented at Water Pollut. Contr. Fed., Bal Harbour, Florida, October 1, 1964. 28 p. (Unpublished.)

Descriptors: Wastewater disposal, Rates of application, Soil types, Reviews, Surveys.

The distribution of liquid waste-land disposal systems by type of waste, application technique, and geographic location has been presented. The over 2,000 reported installations, spread over many states with vastly different climatic conditions, have been used for the disposal of different wastes, and have had great diversity in the waste application techniques used.

A review of the literature revealed that the median application rates at seepage ponds, ridge and furrow, and spray systems were 1.5, 0.74, and 0.22 inches per day, respectively. Sand soils were used almost exclusively at seepage pond installations, while soils with poorer infiltration and percolation rates were usually used at ridge and furrow, and spray sites. Cover vegetation reported in the literature is described and its use at soil systems reviewed.

284 I INVESTIGATIVE PROCESSES FOR THE USE OF RECLAIMED WASTEWATER FOR IRRIGATION IN SOUTHERN CALIFORNIA

Hirsch, L., P. F. Pratt, and S. J. Richards
In: Proc. 4th Ind. Water Waste Conf., University of Texas, Austin, 1964. p. C20-C48.

Descriptors: Dissolved solids, Greenbelts, Water reuse, California, Salinity.

The irrigation of Balboa Park and Mission Bay Park in San Diego with reclaimed water was investigated. In addition scenic freeway greenbelts have a daily water requirement of 45,000 gal. per mile. Procedures for soil leaching and salinity appraisal are given. The results showed that sodium hazard would not be adverse, none of the waters having an exchangeable sodium percentage more than 70 percent. The salinity hazard was high (1,500 mg/l TDS). However, use of high salinity tolerant plants and a 10-20 percent excess for leaching would give satisfactory results.

285 S EFFECT OF DIFFERENT PUTREFYING WASTE-WATER SLUDGE APPLICATIONS ON THE WATER-STORAGE CAPACITY AND YIELD OF A SANDY SOIL

Husemann, C., and D. Pannier
Z. Kulturtech. (Berlin), 3: 193-204, 1962. Abstr., Soils Fert., 27: 327(2374), 1964.

Descriptors: Rates of application, Vegetable crops, Crop response, Soil physical properties.

Applications of sewage sludge markedly increased the water-holding capacity of the soil and increased yields of lettuce. Effectiveness of the sludge depended on its source, composition, consistency, and preliminary treatment.

286 M THE PURIFYING EFFECT OF DIFFERENT METHODS OF SEWAGE-WATER TREATMENT IN INVESTIGATIONS OF BERLIN SAND SOIL

Husemann, C., and J. Wesche
Z. Kulturtech. (Berlin), 3: 291-307, 1962. Abstr., Soils Fert., 27: 153(1097), 1964.

Descriptors: Germany, Flood irrigation, Border irrigation, Furrow irrigation, Sprinkler irrigation.

Surface flooding (soil filters), border irrigation, contour-furrow irrigation, sub-irrigation, and sprinkling irrigation were compared. Soil filters were unsatisfactory, leaving a high content of N and other plant nutrients in the seepage water. The other irrigation methods were better; but, by far, the best was sprinkling irrigation which resulted in almost complete purification of the seepage water.

287 M TREATMENT OF SEWAGE AS AN AID TO ECONOMICAL DISPOSAL

Isaac, P. C. G.
Compost Sci., 3: 7-11, 1962.

Descriptors: Costs, Wastewater disposal.

Disposing of sewage by irrigation and land application can assist in reducing disposal costs.

288 M SEPTIC TANK EFFLUENT PERCOLATION THROUGH SANDS UNDER LABORATORY CONDITIONS

Jones, J. H., and George S. Taylor
Soil Sci., 99: 301-309, May 1965.

Descriptors: Septic tanks, Clogging (soil), Aerobic conditions, Organic loading.

In the gravel-sand column in which septic tank effluent first percolates over the gravel, the zone of most rapid clogging is the sand-gravel *interface. Organic and inorganic deposits are also highest in the interfacial region. The gravel accumulates up to 20 percent of the total deposits, and because of its better aeration affords higher organic decomposition. Soil clogging under effluent loading occurs 3 to 10 times faster under an anaerobic than under an aerobic environment, and sands of initially high hydraulic conductivity are clogged at a much slower rate than those of initially low conductivity. Under aerobic conditions, there are three distinct phases of clogging in sand. The first is a period in which the conductivity declines to near 25 percent of its initial value. During the second phase, the conductivity fluctuates near the latter value for many months and declines slowly to near 10 percent of the original conductivity. In the third phase, the conductivity drops rather sharply to 1 or 2 percent of its initial value.*

289 M THE FATE OF ABS IN SOILS AND PLANTS

Klein, A. Stephen, David Jenkins, and P. H. McGauhey
J. Water Pollut. Contr. Fed., 35: 636-654, May 1963.

Descriptors: Soil types, Biodegradation, Crop response, California, Primary effluent.

Adsorption and biodegradation of alkyl-benzene sulfonate (ABS) from water percolating through each of five soil types under saturated and unsaturated, sterile and biologically-active, and under continuous and intermittent flow conditions, were studied. The results are discussed and significant conclusions enumerated. Water solutions of ABS were compared to primary sewage effluents containing added amounts of ABS on both fertilized and unfertilized soils. Sunflower and barley were grown in water culture at ABS concentrations of 0, 10, and 40 mg/l. Sunflower, barley, and Lupinus albus were grown in soil at ABS concentrations of up to 50 mg/l. Although ABS severely inhibited growth in water culture, only sunflower was adversely affected in soil. Growth of plants irrigated with sewage far surpassed those irrigated with water, regardless of soil fertilization practices or the addition of up to 15 mg/l ABS to the sewage. It was concluded that irrigation with sewage is beneficial to plants despite the presence of ABS in any amount likely to occur in sewage at the present time.

290 I UTILIZATION OF DOMESTIC SEWAGE AND INDUSTRIAL WASTES BY BROAD IRRIGATION

Kreuz, Councillor
Sewage Works J., 8(2): 348, March 1963.

Descriptors: Design data, Border irrigation, Soil chemical properties, Fertilizer value, Germany.

After sewage solids are removed 80 percent of the potassium, 75 percent of the nitrogen and 52 percent of the phosphoric acid remains, making the effluent a valuable fertilizer. With proper care, such as harvesting, the effluent from the sewage of 80 people can be put on an acre of land. The study was carried out in Germany.

291 M THE UTILIZATION OF CITY SEWAGE IN CHINA
Kuo, T.
Vattenhygien. (Sweden), 21: 84-87, 1965.

Descriptors: China, Wastewater disposal, Human diseases, Grain crops, Fish farming.

The author discusses the increasing utilization of municipal sewage for irrigation and fish culture in China. The sewage undergoes preliminary treatment to conform with the standards of public health and to ensure that the contents are suitable for farming and fish culture. Over a number of years, there has been a remarkable increase in the production of wheat, rice, and kelp. The need is stressed for further research into the effects of infiltration of the sewage into the groundwater, and the measures needed to protect soil and crops from extraneous contamination and to prevent the spread of contagious diseases.

292 M POSSIBILITIES OF INCREASING THE FERTILITY OF LIGHT SOILS BY IRRIGATION WITH SEWAGE
Kutera, J.
Zeszyty Probl. Postepow Nauk Roln. (Warsaw), 40B: 239-260, 1963.
Abstr., Soils Fert., 27: 69(465), 1964.

Descriptors: Salinity, Soil chemical properties, Soil physical properties, Poland, Fertilizer value.

Due to the high availability of N, P, and K in sewage, its application in irrigation does not result in salt accumulation. It supplies considerable amounts of organic matter to the soil. In irrigating grassland with sewage, 1 cu.m./ha yielded up to 4.5 kg. of high protein content hay.

293 M RECLAIMING HYPERION EFFLUENT
Laverty, F. B., et al.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 87(SA6): 1-40, November 1961.

Descriptors: Spreading basins, Activated sludge effluents, Rates of application, Deep percolation, Los Angeles, California.

Land filtration was studied as one method of treating activated sludge effluent in Los Angeles for injection in a recharge well. Several modes of operation were attempted with well sorted dune sand as the treatment matrix.

Continuous surface spreading was unsuccessful due to gradual sealing off of the surface by anaerobic slimes. Neither chlorination of the effluent prior to spreading nor increased water depth improved infiltration rates. Continuous spreading with raking of the basin surface allowed an infiltration rate of 2 ft/day to be maintained. This mode required excessive operator time and the effluent fouled the injection well.

Intermittent loading was successful for the entire 6 month test. Rates of 1 ft/day and 34,000 lb BOD per acre per year were maintained. BOD was reduced by 90 percent.

294 M WHY SEWAGE EFFLUENTS MUST BE CHLORINATED
Lehmann, A. F.
Amer. City, 80: 79-81, July 1965.

Descriptors: Pathogenic bacteria, Surveys, Costs, Water reuse.

Growing water reuse and increased recreational requirements on streams and reservoirs are making effluent chlorination not only desirable but imperative in more and more areas.

Microbiologists agree that secondary treatment reduces the number of pathogenic organisms in wastewater, but they also recognize the need for chlorination to reduce them "below demonstrable levels." Unchlorinated raw or settled wastewater constitutes a health hazard when discharged to bodies of water with which people may come in contact. Secondary treatment reduces but does not eliminate the risk.

Costs are not prohibitive. Estimates based on observed practices are given.

295 I SPRAY IRRIGATION OF VEGETABLE AND FRUIT PROCESSING WASTES

Luley, H. G.
J. Water Pollut. Contr. Fed., 35: 1252-1261, October 1963.

Descriptors: Pennsylvania, Sprinkler irrigation, Wastewater treatment, Rates of application, Overland flow.

The Heinz Company has successfully used spray irrigation at plants in Salem, New Jersey, and Chambersburg, Pennsylvania, using ground conditions of both high and low permeability and through winters with icing. On the impermeable soil, BOD reductions of 97 percent were obtained by applying the wastewater to the soil at a rate that would allow slow runoff for 100 feet before running off into a river. Application rates were about 1.25 mgd, maximum, to a 52-acre site.

296 M WASTE WATER RECLAMATION: A PRACTICAL APPROACH FOR MANY WATER-SHORT AREAS

Marks, R. H.
Power, 107: 47-50, November 1963.

Descriptors: Los Angeles, California, Operation and maintenance, Groundwater recharge, Water reuse, Sprinkler irrigation.

The author describes the operation of a water reclamation plant at Whittier Narrows in Los Angeles County. The system of treatment and the equipment used are discussed and illustrated. At present, this water is used to recharge groundwater supplies, but the plant could furnish water for other uses if necessary. Such a treatment plant could be used in other areas for recharge, irrigation, and industrial water supplies.

297 M A STUDY OF METHODS OF PREVENTING FAILURE OF SEPTIC-TANK PERCOLATION SYSTEMS

McGauhey, P. H., and J. H. Winneberger
University of California, Berkeley, SERL Report No. 65-17, October 1965.

Descriptors: Clogging (soil), Septic tanks, Aerobic conditions, Flood irrigation.

Any soil continuously inundated will lose most of its initial infiltrative capacity. In leaching systems, this leads to failure if the system is designed on the basis of initial infiltration rates. Seven criteria are given to prevent failure of leaching systems:

1. *Continuous inundation of the infiltrative surface must be avoided.*

2. *Aerobic conditions should be maintained in the soil.*

3. *Initially, the infiltrative surface should be typical of an internal plane in the undisturbed soil.*

4. *Load the entire infiltrative surface uniformly and simultaneously.*

5. *Avoid abrupt changes in particle size between trench fill material and soil at the infiltrative surface.*

6. *Provide maximum sidewall surface and minimum bottom surface per unit volume of effluent.*

7. *Minimize suspended solids in the effluent.*

298 I THE CONTROL OF SPHAEROTILUS NATANS
McKeown, J. J.
In: Proc. 17th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1962. p. 440-453.

Descriptors: Spray disposal, Design data, Pulp and paper wastes, Operation and maintenance, Georgia.

The growth of the slime, Sphaerotilus natans, during winter months has on occasion become a nuisance to net fishermen in the Altamaha River in Georgia. The Jesup Div. of Rayonier, Inc., at Jesup, Georgia, discharged 45 mgd of Kraft mill waste into the river. The discharge, which provided the necessary nutrients, was correlated to slime growth in the river.

A twenty acre system of sandy soil was designed to handle the strong waste (1 mgd 1,000 mg/l BOD) with the weak waste (44 mgd 100 mg/l BOD) discharge to the river. The maximum spray application was found to be 3-5 in./day. Average loadings were 1.8 in./day and 420 lb/acre/day of BOD. Alfalfa, sweet clover and tall fescue were grown and shallow test wells surround the site. A slight soil plugging tendency occurred after 60-100 in. were applied, however, discing the top few inches allowed the area to receive additional waste.

299 M THE SANTEE RECREATION PROJECT, SANTEE, CALIFORNIA SUMMARY REPORT, 1962-1964

Merrell, J. C., Jr., Albert Katko, and H. E. Pintler
Public Health Service, Cincinnati, Ohio, Publ. No. 999-WP-27,
December 1965. 69 p.

Descriptors: Viruses, Coliforms, Tertiary treatment, Santee, California, Recreational facilities.

This paper presents the results of a study of the Santee, California recreational lakes. These lakes were deliberately planned to utilize the community's reclaimed sewage effluent. The seven-agency cooperative study evaluated the fate of viruses along with total and fecal coliform and fecal streptococci through the conventional secondary treatment process, the tertiary processes, and the recreational lakes. The correlating physical and chemical data are presented along with a biological study of the lakes and related land area. Discussions of eutrophication, vector control, epidemiology, and the social acceptance and ecology of the entire recreational park are developed. The study concludes that the treatment provided by intermittent sand filtration has met the nutrient requirements of the emerging ecology and that no health hazards have been demonstrated by the viral or other findings for the present recreational uses of boating and fishing.

300 M ADVANCED TREATMENT OF WASTE WATERS FOR REUSE

Middleton, F. M.
Water Sewage Works, 111: 401-410, 1964.

Descriptors: Costs, Water reuse, United States, Tertiary treatment.

Some examples of wastewater reuse and the need for advanced waste treatment processes are briefly discussed. The status of advanced waste treatment processes is reviewed by presenting nine process descriptions which represent progress reports of studies in this area. No firm cost figures for these processes could be given; however, estimated costs are made based on projections of data at hand.

301 I SPRAY IRRIGATION FOR INDUSTRIAL WASTE DISPOSAL

Parker, R. R.
Can. Muni. Util., 103: 28-32, July 1965.

Descriptors: Sprinkler irrigation, Canada, Tannery wastes, Rates of application, Winter storage.

The author, an engineer with Beardmore and Company, Limited, Acton, Ontario, has worked on a spray irrigation system for this Canadian tannery. The systems disposed of 150 million gallons in a six-month period from May to November for the past 12 years. Winter wastes are lagooned. Details on application rates and type of soil and cover crop are not given.

302 M RECLAIMING USED WATER

Parkhurst, John D.
Amer. City, 78: 83-85, October 1963.

Descriptors: Los Angeles, California, Groundwater recharge, Activated sludge effluents, Groundwater contamination, Water reuse.

The Whittier Narrows plant in Los Angeles is designed to salvage the treated wastewater for reuse rather than dump it into the ocean. A constant 10 mgd of raw sewage is diverted from the trunk sewer to the activated sludge plant, which consists of two primary sedimentation tanks (detention 2.6 hr), three aeration tanks (25% return, detention 5.8 hr), and five final settling tanks (detention 2.2 hr). This treatment, followed by chlorination, produces an effluent averaging about 10 mg/liter BOD and soluble solids. Percolation through the ground after spreading recharges the aquifer for underground storage and further reduces the impurities. All by-products (e.g., sludge) go back into the trunk sewer for removal and disposal at existing downstream treatment facilities.

303 M PROGRESS IN WASTE WATER RE-USE IN SOUTHERN CALIFORNIA

Parkhurst, J. D.
Amer. Soc. Civil Eng., J. Irrigation Drainage Div., 91(IR1): 79-91, March 1965.

Descriptors: Water reuse, Water quality standards, California, Wastewater treatment, Surveys.

The author emphasizes the extensive planning behind Los Angeles County's current water reuse operation. Waste water reclamation falls into two categories: (1) that which is incidental to water pollution control in inland areas; and (2) planned reclamation for the production and reuse of reclaimed water. The latter would be for the purpose of meeting a particular water resource need as in Los Angeles County. Factors and conditions which justify water reclamation facilities are discussed. The plan developed in southern California should stimulate interest in *planning for reuse in other communities that are concerned about their future water resources. The author states, "The question is not whether there will be water reuse, but when, where, and how well it will be implemented."*

304 M AN INEXPENSIVE BIOASSAY AIMED AT THE AGRICULTURAL DISPOSAL OF WASTE WATERS
Prat, S., and V. Sladecek
Hydrobiologia (The Hague), 23: 246-252, 1964.

Descriptors: Surveys, Vegetable crops, Sprinkler irrigation, Netherlands.

A method of bioassay is described for detecting the toxicity of wastewaters to germinating plant seeds and evaluating the suitability of the waters for irrigational use. Seeds of the mustard, Sinapis alba, are placed in petri dishes on Silon or nylon textile fabric and irrigated with the water under investigation. They are kept in the dark at 16°-20° C and observed daily for three days. The numbers of germinating seeds, the lengths of the rootlets, and the ratios of root length to hypocotyl length are recorded as indices of water quality. Stimulation of growth of rootlets, as well as toxicity of the water, can be detected by comparison with controls.

305 M A METHOD OF APPRAISING IRRIGATION RETURNS
Reutlinger, S., and J. A. Seagraves
J. Farm Econ., 44: 837-850, 1962.

Descriptors: North Carolina, Costs, Crop response, Economic feasibility, Furrow irrigation.

A method of computing the increased crop yield from a series of irrigation experiments is described. The method is explained with the aid of an example in which an expected yield increase and synthetic cost data are used to evaluate the profitability of investing in irrigation systems for tobacco in the Coastal Plain of North Carolina.

306 M DEGRADATION OF ABS AND OTHER ORGANICS IN UNSATURATED SOILS
Robeck, Gordon G., Jesse M. Cohen, William T. Sayers, and Richard L. Woodward
J. Water Pollut. Contr. Fed., 35: 1225-1236, October 1963.

Descriptors: Soil chemical properties, Biodegradation, Aerobic conditions, Coliforms, Ohio.

Soil lysimeter studies showed the alkyl benzene sulfonate (ABS) in a septic tank effluent can be degraded from 5 to 35 mg/l to less than 0.5 mg/l if applied properly to certain unsaturated soils. Under intermittent loading on a daily basis aerobic organisms survived. Most sandy soils handled at least 0.5 to 1.0 foot per day of waste. Organisms usually found in sewage and soil were able to degrade ABS, 2,4,5,-T 2,4-D, and o-cresol if time were allowed to adjust and handle new organics in the waste. Coliform organisms, odor, turbidity, and COD were greatly reduced and nitrification took place when the ABS was degraded below 0.5 mg/l.

307 M FACTORS INFLUENCING THE DESIGN AND OPERATION OF SOIL SYSTEMS FOR WASTE TREATMENT

Robeck, G. G., et al.
J. Water Pollut. Contr. Fed., 36: 971-983, August 1964.

Descriptors: Soil types, Organic loading, Rates of application, Ohio, Design data.

A series of 50 lysimeter tests were conducted at Robert A. Taft Sanitary Engineering Center to determine the factors influencing the design and operation of soil system for waste treatment. The study indicated the following features help effect a 90 to 95 percent reduction of ABS and other COD components in a septic tank effluent.

1. Start with a soil that has 0.5 to 1 percent organic matter, or at least an adsorptive additive to provide retention at an early stage.

2. Use a soil that has an effective size of about 0.1 to 0.3 mm to have low enough permeability.

3. Make the depth to groundwater be at least 10 ft.

4. Start with a 1 gpd/sq ft loading, but increase a month later to 3 gpd/sq ft.

5. Apply the waste three to six times per day.

6. Mix in a 1/2 in. seed from another biologically active bed with the soil in lysimeter to insure early treatment.

308 M THE EFFECTS OF TRACE ELEMENTS ON THE EXHAUSTION OF SEWAGE-IRRIGATED LAND

Rohde, G.
J. Inst. Sewage Purif. (London), Pt. 6: 581-585, 1962.

Descriptors: Berlin, Germany, Crop response, Soil physical properties, Soil contamination, Heavy metals.

At the Berlin sewage farm, some of the soil has recently shown signs of exhaustion, and crop yields have fallen. Samples of exhausted soil and soil on which healthy plants were growing were examined, particularly for trace elements. The results were compared with analysis of similar samples from a sewage farm in Paris where signs of exhaustion had also been observed. The soil at the Berlin farm is sandy and acid, while that at the Paris farm is rich in lime. The results of the analyses are tabulated and discussed. It appears that the main cause of exhaustion at both Berlin and Paris is the presence of high concentrations of copper and zinc.

309 I RIDGE-AND-FURROW IRRIGATION FOR INDUSTRIAL WASTES DISPOSAL

Schraufnagel, F. H.
J. Water Pcllut. Contr. Fed., 34: 1117-1132, November 1962.

Descriptors: Costs, Design data, Furrow irrigation, Rates of application, Wisconsin.

The author surveyed the ridge-and-furrow irrigation methods that were used by many industries for the disposal of their wastes. The investigated industrial wastes included cannery wastes, milk and dairy wastes, meat and poultry wastes, municipal wastes and other wastes such as tannery and chemical wastes. Factors related to the design of the system are summarized as follows:

1. *Application rate. The principal factor in loading rate is the ability of the soil to transmit water. If it is expected to get a stabilized water in the soil from an organic waste, aerobic conditions must be maintained in the soil. The expected rate of flow must take adequate rest periods into consideration.*

2. *Design. There is such a large spread in volumetric loadings to different soils, that basing a proposed system on a single existing one could easily result in over- or underdesigning by a factor of 10. A rule of thumb figure (such as 10,000 gad) as a design basis would limit the error, but one could*

still be in error by 4 to 5 times. Detailed soil maps, percolation tests or soil borings are useful in determining the proper rate.

3. *Vegetation. For winter operation and for those soils which can tolerate high application rates, vegetation is apparently of little significance. However, on those soils which on the average can handle only a few thousand gallons per acre daily, the assistance by vegetation can mean the difference between success and failure. Even when dormant, the grass may assist in keeping the soil loose and also provide some protection from deep freezing in the winter months.*

4. *Drain tiling. Drain tiling may improve the effluent quality. Tiling at a depth greater than 2.5 ft below furrows will usually be satisfactory providing the BOD is less than 1,000 mg/l and wastes are applied intermittently. The drain tiles are often laid perpendicular to the furrow bottoms. If the 2.5 ft minimum distance cannot be met and still obtain gravity discharge, it may be possible to install the tile under the ridge section where the wastes would have to infiltrate laterally for several feet.*

5. *Irrigation water quality. The characteristics of a water or waste that determine its quality for irrigation use are (a) total concentration of dissolved constituents, (b) sodium adsorption ration (SAR), (c) concentration of bicarbonate, and (d) concentration of boron and other toxic substances.*

310 I DISPOSAL OF HIGH ORGANIC CONTENT WASTES ON LAND
Scott, Ralph H.
J. Water Pollut. Contr. Fed., 34: 932-950, September 1962.

Descriptors: Sludge disposal, Groundwater contamination, Pulp and paper wastes, Dairy wastes.

The author describes the practical aspects of strong waste application to land and cites experience gained from the practice. Disposal of liquid digested sludge, cheese whey, and spent sulfite liquor is discussed. Examples and cost figures are given. Careful planning is needed to safeguard groundwater quality, especially where spent sulfite liquor is involved.

311 M SURVEY OF SEWAGE DISPOSAL BY HILLSIDE SPRAYS
Sepp, E.
Bur. Sanit. Eng., Calif. State Dept. Pub. Health, March 1965. 35 p.

Descriptors: Septic tanks, Sprinkler irrigation, Sacramento, California, Rates of application, Odor.

Sewage disposal by hillside spraying was studied at 30 treatment plants. Fourteen of these plants have secondary treatment and the remaining have only septic tanks or Imhoff tanks. Only 10 plants have chlorination. Design and operation of the sprinkling systems were studied, giving types of nozzles and pipe lines used and causes and effects of nozzle clogging. Application rates, operation data and appearance of the spray sites are described. Results of bacteriological and chemical tests, travel of airborne bacteria, and odor and insect problems are discussed. It is recommended that hillside spraying be used only for summer loads. The use of hillside spraying is to be discouraged for year-round operation.

312 M PUBLIC HEALTH ASPECTS OF WASTE WATER UTILIZATION IN ISRAEL
Shuval, Hillel I.
In: Proc. 17th Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1962. p. 650-665.

Descriptors: Groundwater recharge, Crop response, Public health regulations, Flood irrigation, Israel.

It is estimated that total water reserves in Israel can be increased by at least 10 percent through wastewater reclamation programs. Early efforts were devoted to direct agricultural irrigation with treated sewage effluent. Some 50 projects of this type are in operation. Results have been good, and there has been no indication of any resulting menace to the public health. However, due to restrictions by the Ministry of Health as to the types of crops that can be irrigated and other engineering and health considerations, more recent efforts are being directed toward groundwater recharge with treated wastewater. A major groundwater recharge project in the Dan Region is described.

313 S USING SLUDGE MEANS CLEAN STREAMS FOR PENNA. TOWN
Sine, Richard L.
Compost Sci., p. 40-41, Winter 1963.

Descriptors: Pennsylvania, Sludge disposal.

Sewage sludge as a soil conditioner to improve municipal property is used.

314 M THE EFFECT OF LEACHING SALINE ALKALI SOILS WITH IRRIGATION WATERS OF DIFFERENT KINDS ON THE PERMEABILITY AND THE COMPOSITION OF THE SOILS AND THE COMPOSITION OF THE LEACHATES

Sprivastava, P. B. L., and C. L. Mehrotra
J. Indian Soc. Soil Sci. (Delhi, India), 10: 93-98, 1962.

Descriptors: Soil chemical properties, India, Wastewater disposal.

Results of laboratory tests are reported on the effect of leaching with sewage, canal, and well waters, in the absence or presence of 1/2 to 1 ton $CaSO_4$, on the conductivity, Ca + Mg, monovalent cation and anion contents, and percolation in different soils (pH 8.3-8.85) of originally 31-51 percent saturation.

Canal waters tended to increase soil alkalinity but improved percolation, especially in combination with small doses of $CaSO_4$. Sewage waters decreases salinity and alkalinity in soils affected by the application of canal waters.

315 M FROM POLLUTION PREVENTION TO EFFLUENT REUSE

Stanbridge, H. H.
Water Sewage Works, 111: 446-451 and 494-499, 1964.

Descriptors: Water management (applied), Water quality standards, England, Aerobic conditions.

Recent methods and future proposals for the reuse of effluents that now pollute England's rivers are presented. The need for greater conservation of water resources is discussed in relation to the rapidly growing needs of industries and the public in various areas of England and Wales. The author concludes: "As the demand for water increases, and sewage effluents and river water are used more extensively, quality will be determined by the use to which the water is to be put rather than by the need to prevent nuisance or support fish."

316 M CONTROL OF WATER POLLUTION BY WASTEWATER UTILIZATION: THE ROLE OF THE WATER POLLUTION CONTROL FEDERATION

Steffen, A. J.
Water Sewage Works, 111: 384-385, 1964.

Descriptors: Water reuse, Water quality standards, Reviews, Conferences.

The Water Pollution Control Federation has stressed the great importance of wastewater reuse in its Statement of Policy, Point No. 9: "That wastewater represents an increasing fraction of the nation's total water resource and is of such value that it might well be reclaimed for beneficial reuse through the restoration of an appropriate degree of quality." The concern of the WPCF is evidenced by the many papers and discussions on this subject that are presented at Association and Federation publications and by the various medals and awards presented for research in this field.

317 M WASTE WATER RECLAIMED FOR GOLF COURSE USE
Stone, Ralph
Pub. Works, 94: 88-90, March 1963.

Descriptors: California, Groundwater recharge, Greenbelts, Recreational facilities, Spreading basins.

Reclaimed water from the Ontario, California sewage treatment plant is used at the rate of 0.5 mgd for decorative lakes and golf course irrigation. Another 5.5 mgd is diverted to nearby spreading basins for groundwater recharge and other irrigation.

Before use on the golf course, the water is retained 30 days in stabilization ponds with 24-hour chlorine contact time and post-chlorinization as it is pumped to the golf course.

318 M ECONOMICS OF GROUNDWATER RECHARGE
Todd, David K.
Amer. Soc. Civil Eng., J. Hydraul. Div., 91(HY4): 249-270, 1965.

Descriptors: Economic feasibility, Groundwater recharge.

Many variables are involved in determining the cost and economic advantage to be gained from artificial recharge of groundwater aquifers. Information upon which to base such estimates is scarce. The size, purpose, and method of recharge are significant factors, as are land and water costs. Data from several recharge operations are presented in an attempt to arrive at a logical basis for estimating these costs.

319 M THE EFFECT OF IRRIGATION WITH TOWN SEWAGE ON THE PRODUCTION OF VARIOUSLY FERTILIZED WINTER RAPE
Trybala, M.
Zesz. Nauk. Wyzsz. Szk. Roln. Wroclawiu Melior. (Wroclaw, Pol.), 8: 29-42, 1963. Abstr., Soils Fert., 27: 327(2376), 1964.

Descriptors: Poland, Rates of application, Crop response.

Application of 150-350 mm sewage water promoted the growth of rape on unfertilized plots and on plots given minerals P and K.

320 M THE SPREAD OF BACTERIAL CONTAMINATION IN UNDERGROUND WATER
Vaisman, Ya. I.
Hyg. Sanit. (USSR), 29: 21-26, April 1964.

Descriptors: Soil types, Soil physical properties, Groundwater contamination, Coliforms, Soviet Union.

From the data from the literature review at the first of the article, it is concluded that the existing data are extremely controversial with respect to the quantitative characteristics of the main limiting factor which should be made the basis of calculations for determining the boundaries of the second belt of the safety zone for underground water supply sources. This precipitated a study of bacterial spread in underground water. It was concluded that the colon bacillus can go a distance of over 850 meters in the ground current in medium-grain sand with cross-layers of gravel and pebble deposits, and that 400 days should be necessary for complete self-purification of the ground flow from bacterial contamination.

321 M DEVELOPMENTS IN WASTE WATER REUSE
Viessman, Warren, Jr.
Pub. Works, 96: 138-140, April 1965.

Descriptors: Groundwater recharge, Economic feasibility, Santee, California, Recreational facilities, Water reuse.

The author discusses several possible reuse applications for reclaimed wastewater. Among these are irrigation, industrial use, and groundwater recharge. Examples of reuse are cited. Consideration is given to the quantities of wastewater available and to those operations which this would satisfy economically. The Santee project in southern California is cited as an excellent example of the use of sewage effluent for recreational purposes.

322 S TEST OF SEWAGE SLUDGE FOR FERTILITY AND TOXICITY IN SOILS
Vlamis, J., and D. E. Williams
Compost Sci., 2(1): 26-30, 1961.

Descriptors: Ion exchange, Salinity, Sludge disposal, California, Reviews.

California researchers report on studies comparing the growth of plants receiving applications of sludge and chemical fertilizers. Both fertility and toxicity are considered.

323 M OXIDATION PONDS AND USE OF EFFLUENT IN ISRAEL
Watson, John L. A.
Effluent Water Treat. J. (London), 3: 150-153, 1963.

Descriptors: Oxidation lagoons, Water reuse, Groundwater recharge, Furrow irrigation, Fish farming.

Oxidation ponds are used as aids in reclaiming sewage effluents. They provide economic and safe treatment of sewage for an effluent suitable for reuse. Principal reuse to date has been for irrigation; but groundwater recharge, makeup water for fish-breeding ponds, and industrial reuse are contemplated.

324 M UPDATING WATER RESOURCES THINKING TO MEET SPACE AGE REQUIREMENTS
Watson, K. S.
Water Sewage Works, 111: 160-164, 1964.

Descriptors: Water reuse, Water management (applied), Water quality standards.

In examining progress in the water resources field, the author considers water management, wastewater reuse, advanced waste treatment, desalination, and pollution control, including enforcement.

325 S USING TREATED SEWAGE EFFLUENT FOR CROP IRRIGATION
Weiss, Rudolph H.
Compost Sci., 2(3): 33-34, 1961.

Descriptors: Texas, Design data, Sludge disposal, Flood irrigation.

The city of Kerrville, Texas solves a stream pollution problem and provides water for growing crops at the same time. The treatment plant design and operation are given. The wet digested sludge is diluted with sewage effluent and discharged onto the land in conjunction with the regular irrigation program, thereby eliminating the need for sludge drying beds and the tedious labor involved. The operation won Kerrville an award for the most efficient disposal of sewage sludge in the State of Texas.

326 M IRRIGATION AS A SEWAGE REUSE APPLICATION

Wells, W. N.
Pub. Works, 92: 116-118, August 1961.

Descriptors: Wastewater treatment, San Antonio, Texas, Human diseases, Wastewater disposal, Reviews.

Advantages and limitations in the use of sewage for irrigation at San Antonio, Texas, are reviewed. Disposal by irrigation has avoided the need for a high degree of treatment and has given farmers a dependable supply of irrigation water. Data are shown concerning the chemical content of the water and the types of crops grown. Currently, 16 mgd (approximately one-fourth of the plant effluent) are used to irrigate 4,000 acres for growing cotton, castor beans, feed grains, and forage crops.

The literature on health hazards in sewage irrigation was reviewed as supporting evidence that the use of sewage effluents for growing such crops is not hazardous.

327 I IRRIGATION DISPOSAL OF WASTES

Westenhouse, Ray
Tappi., 46: 160A-161A, 1963.

Descriptors: Spray disposal, Rates of application, Flood irrigation, Forage crops, Pulp and paper wastes.

Land disposal of Kraft mill condensates was accomplished by sprinkler irrigation methods. Application rates of 0.5 in./day produced slight surface flooding. Sixty acres of land provided sufficient pasture for 80-100 head of livestock. Burning of vegetation by the 150° F condensates was controlled by the use of higher system pressures and increased trajectory from the nozzle outlet. More than 50 percent of the total mill waste load was disposed of on land by this method.

328 M REUSE OF EFFLUENT IN THE FUTURE WITH AN ANNOTATED BIBLIOGRAPHY
Whetstone, George A.
Texas Water Development Board, Austin, Report 8, December 1965.
187 p.

Descriptors: Texas, Bibliographies, Recreational facilities, Groundwater recharge, Water reuse.

An excellent comprehensive review of the literature dealing with reuse of effluent for purposes of irrigation, recreation, industry, groundwater recharge, and potable water supply. There is a total of 663 abstracts, dating from 1892 through 1965. The literature reviewed is broad in scope, covering historical development, current status, and unresolved issues in the reuse of effluents. The abstracts are indexed by authors and subject, and are presented in chronological order.

329 M EFFECT OF ORGANIC MATTER CONTENT OF THE SOIL ON INFILTRATION
Wischmeier, W. H., and J. V. Mannering
J. Soil Water Conserv., 20: 150-152, 1965.

Descriptors: Soil physical properties, Soil types, Soil chemical properties.

Measurements of soil physical properties were obtained from 44 different soils and related to runoff. Soil texture classes included sandy loam, loam, silt loam, clay loam, silty clay loam, and silty clay. Organic matter contents ranged from 1 to 4 percent, and slopes from 4 to 14 percent.

The organic matter content of the soil was the measured variable most closely correlated with runoff. Results of linear regression analyses are discussed.

The study indicated that the entry of rain into the soil was influenced much more by the organic matter content and by management practice than by texture and topography.

330 I IRRIGATION DISPOSAL OF INDUSTRIAL WASTES
Wisniewski, Theodore
Pub. Works, 92: 196, July 1961.

Descriptors: Furrow irrigation, Wisconsin, Rates of application, Sprinkler irrigation.

Spray irrigation systems and ridge and furrow systems have both been successfully used in Wisconsin at rate up to 10,000 gpd per acre. An important consideration is to keep the solids loading below one pound per square yard per day.

331 M FUTURE DEVELOPMENTS IN WATER SUPPLY
Yackey, Harold H.
J. Amer. Water Works Ass., 53: 409-412, April 1961.

Descriptors: Water reuse, Wastewater treatment.

The author discusses future water needs and how existing facilities should be expanded to meet these needs. Salvaging wastewater is one big step that can be taken.

SECTION VI

ABSTRACTS 1966 THRU 1970

332 I NEW YAKIMA WASTE TREATMENT SYSTEM OVERCOMES GROUNDWATER INFILTRATION
Anonymous
West. City, 37: 30-31, 1966.

Descriptors: Food processing wastes, Rates of application, Washington, Sprinkler irrigation, Design data.

In 1957-58, Yakima, Washington, had constructed a separate industrial sewer, located to serve four major fruit and vegetable processing plants, and a high pressure irrigation system. The system did not operate well and was expanded in 1964. Reasons given for poor performance included lack of adequate cover crop, overloading, overgrazing by cattle with compaction of soil, and necessity to irrigate in freezing weather. The original loading was 1.5 inches per day but actual loading averaged 2.1 to 2.45 inches per day. The irrigation site was expanded from 52 to 125 acres providing for an application rate of 1.23 inches per day.

333 M IMPROVE EFFLUENT WITH SPRAY IRRIGATION EQUIPMENT
Anonymous
Surv. Munic. Cty. Eng. (London), 127(3862): 41-42, 1966.

Descriptors: Wastewater treatment, Spray disposal, Canada, Design data, Primary effluent, Warwick, B.C.

An illustrated description is given of spray irrigation equipment installed at Warwick sewage works in May, 1966, as the initial stage of alleviating overloaded conditions. After primary sedimentation, effluent is pumped through standard farm irrigation equipment over an area of 7.2 acres of grassland (which is divided into two plots, each of which is allowed a 14-day rest period) before drainage to the River Avon.

334 S WHERE DOES THE GRASS GROW GREENEST? WHERE SEWAGE SLUDGE AND FERTILIZER ARE MIXED WITH SEED

Anonymous
Water Pollut. Contr. (London), 65(4): 26-28, August 1966.

Descriptors: Canada, Forage crops, Recycling nutrients.

In order to find a use for sewage sludge as fertilizer at Kitchener, Ontario, dried, liquid or filtered sludge, together with superphosphate, was spread over or mixed with the topsoil of test areas on a filled-in municipal waste tip, and grass seed was sown. The best growth was produced when the dried sludge was used. The filtered wet sludge used with the superphosphate produced too strong a mixture.

335 M EXTENDS SPRAY IRRIGATION SCHEME FOR EFFLUENT IMPROVEMENT

Anonymous
Surv. Munic. Cty. Eng. (London), 129(3905): 26-27, 1967.

Descriptors: Oxidation lagoons, Planning, Spray disposal, Warwick, B.C., Canada, Design data.

A description, illustrated by plan and photograph, is given of extensions and modifications to the original spray irrigation system for disposal of effluent at Warwick sewage works; these include the construction of a lagoon which receives humus-tank effluent, and from which the original irrigation area is now sprayed, and the use of an additional 10-acre plot (divided into 2 equal plots to allow a rest period for each) onto which storm sewage from the storm tank is sprayed.

336 S INCREASED INCOME FROM SLUDGE SPRAYING

Anonymous
Water Waste Treat. J., 12: 32, 1968.

Descriptors: Sludge disposal, Recycling nutrients.

East Kilbridge has completed its second year of land disposal of digested sewage sludge, selling to farmers in a 15-mile area. Undigested sludge is disposed of at sea.

337 S HOW TO SAVE TAXES AT THE SEWAGE PLANT
Anonymous
Compost Sci., 11(1): 21, January-February 1970.

Descriptors: Pennsylvania, Public acceptance, Sludge disposal.

Allentown, Pennsylvania, is getting citizens to use its sewage sludge as a soil conditioner.

338 I WASTEWATER DISPOSAL ENHANCES AN AREA'S ECOLOGY
Anonymous
Ind. Water Eng., 7: 18-22, March 1970.

Descriptors: Paris, Texas, Overland flow, Forage crops, Food processing wastes, Water quality data.

The Campbell Soup Company's plant in Paris, Texas, discharges 3-4 mgd of plant effluent to a field where grasses are grown. Besides producing a salable crop from once badly eroded land, about 2 mgd flows into a stream bed, allowing the stream to flow year-round. This stream is going to be used to feed an artificial lake of from 40-150 acres. Tests on land disposal at a plant in Napoleon, Ohio, produced BOD reductions of 90 percent in a few hundred feet of overland flow.

339 M ENGINEERING FEASIBILITY DEMONSTRATION STUDY FOR MUSKEGON COUNTY, MICHIGAN, WASTEWATER TREATMENT-IRRIGATION SYSTEM
Anonymous
Fed. Water Quality Admn., Washington, D.C., Water Pollut. Contr. Research Series, 11010 FMY 10/70, October 1970. 183 p.

Descriptors: Sprinkler irrigation, Muskegon, Michigan, Water management (applied), Soil types, Costs.

Various aspects of the project were investigated including sampling and analyses of wastewaters for a variety of parameters, a review of available information concerning the effect of trace elements on soils and crops, laboratory tests of the treatability of the combined wastewaters by lagoon treatment, the development of a simulation model to assist in analyzing the volume and water quality aspects of a treated wastewater storage lagoon, soils and groundwater field and office studies regarding the management of groundwater levels to insure an adequate aerobic treatment zone in the soil as well as to prevent ponding in the site area, and *investigations of certain agricultural aspects in using treated wastewaters as spray irrigation water. The results of this work demonstrated the feasibility of the proposed project based on information developed during the study. The highlights are that the wastewaters do not contain constituents having concentrations that would interfere with use of these wastewaters as agricultural irrigation waters; the treatability of the wastes by the proposed lagoon treatment system was confirmed by the laboratory work; and the feasibility of management of the groundwater levels within the irrigation site area by drainage wells and tile was established by the investigations.*

340 M REUSE OF MUNICIPAL WASTE WATER
Amramy, A.
Civil Eng., 38: 58-61, May 1968.

Descriptors: Israel, Water quality standards, Nitrate contamination, Groundwater recharge, Water reuse.

This author feels that only one type of wastewater use is complete in itself--groundwater recharge. The work that he has done in Israel has shown that this can be successfully accomplished, although final calcium and nitrate concentrations in the groundwater were too high to be acceptable as drinking water.

341 M SANITARY-HELMINTHOLOGICAL EVALUATION OF SEWAGE FARMS UNDER CLIMATIC CONDITIONS OF THE APSHERON PENINSULA
Amirov, R. O., and D. A. Salimov
Hyg. Sanit. (USSR), 32: 437-439, April 1967.

Descriptors: Furrow irrigation, Climatic data, Flood irrigation, Soil types, Soviet Union.

Biological characteristics of sewage from Baku are given. High percent of viable helminth eggs is found in the municipal sewage (54.4). Sewage is treated by Imhoff process. The treated sewage is used for irrigation because of poor sandy soil and lack of rainfall. It was found irrigation by flooding contaminated vegetables. There were no viable eggs found after two months in the soil. Investigations show sewage can be successfully used to irrigate eastern part of the Apsheron Peninsula. Recommends irrigation on thermal processed food only, and only by furrow irrigation. Climatic information given.

342 I PERCOLATION OF CITRUS WASTES THROUGH SOIL
Anderson, D. R., et al.
In: Proc. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1966. p. 892-901.

Descriptors: Furrow irrigation, Food processing wastes, Monitoring, California, Rates of application.

Wastewater from the Lemon Products Division of Sunkist Growers in Corona, California, is spread on the land in furrows. A flow of 0.82 mgd with a mean COD of 5,200 mg/l, is applied to 66 acre plots for 4 months at a time. The application is 6 in./day and the average liquid loading is 2.7 in./wk for 17 weeks. During the 17 weeks of loading the ground is disced and refurrowed several times. During the 8 months, while the wastewater is being applied to the remainder of the 200 acres, the land lies fallow or is planted to crops. If cropping is practiced, well water is used for irrigation.

As a result of soil water monitoring it was determined that the COD was reduced about 75 percent in the first 3 feet. As a result of percolation the pH, hardness, TDS, and alkalinity of the water increased.

343 M EFFECTIVENESS OF A DEEP NATURAL SAND FILTER FOR FINISHING OF A SECONDARY TREATMENT PLANT EFFLUENT
Aulenbach, D. B., T. P. Glavin, and J. A. R. Rojas
Presented at New York Water Pollut. Contr. Ass. Meet., January 29, 1970. 44 p.

Descriptors: New York, Coliforms, Denitrification, Phosphorus removal, Deep percolation.

A description is given of the Lake George Village, New York, sewage treatment and disposal facilities. Trickling filter effluent has been discharged onto natural sand percolation beds since 1939. The beds are more than 56 feet deep and the effective size of the sand varies from 0.135 mm to 0.25 mm.

Sampling at 10 foot depths in various beds was conducted to determine the extent of wastewater renovation. Coliforms, BOD, and organic nitrogen were almost completely removed. Nitrogen removal was about 50 percent. Phosphorus removal varied from 8 percent for one bed to 60 percent for a percolation bed that is used infrequently. Exhaustion of phosphorus retention in some beds was concluded and subsequent phosphorus leaching into nearby Lake George was postulated.

344 M ARTIFICIAL GROUND WATER RECHARGE: TASK GROUP REPORT

Baffa, J. J., et al.
J. Amer. Water Works Ass., 59: 103-113, January 1967.

Descriptors: Groundwater recharge, Rates of application, Water management (applied), Surveys.

This report presents the findings of a 1964 survey on the practice of groundwater recharge. It was conducted by sending questionnaires to USGS district geologists in each state. Questions were included on the rates of recharge used, and whether studies on the relative economics of recharge versus developing surface supplies had been made. Only five of the 42 states replied yes to the latter question. Reasons given for recharge (in the order of most responses) were: (1) to solve a specific water management problem, (2) to maintain high groundwater levels, (3) to conserve water generally, (4) to prevent salt water intrusion, and (5) to improve the quality of the groundwater.

345 M WASTEWATER RECLAMATION BY GROUNDWATER RECHARGE ON LONG ISLAND

Baffa, John, and Nicholas Bartilucci
J. Water Pollut. Contr. Fed., 39: 431-445, March 1967.

Descriptors: Activated sludge effluents, Tertiary treatment, New York, Rates of application, Groundwater recharge.

With the decrease in groundwater tables and other available supplies of fresh water, many communities are faced with both a water shortage and the danger of salt water intrusion into existing supplies. Research for new supplies has indicated that the use of sewage effluent for groundwater recharge is feasible and bacteriologically safe. Rates of infiltration as high as 3 ft/day have been recorded using activated sludge effluent which has been chemically coagulated and then filtered through sand and carbon. Recharge basins have been found to give the equivalent of tertiary treatment.

346 M ROLE OF SOILS AND SEDIMENT IN WATER POLLUTION CONTROL, PART I

Baily, G. W.
U.S. Dept. Interior, Athens, Ga., Fed. Water Pollut. Contr. Admn., March 1968. 90 p.

Descriptors: Phosphorus removal, Soil chemical properties, Soil physical properties.

This report consists of four sections: (1) nature and properties of soils, (2) chemical character of sewage, (3) behavior of nitrogen in soils, (4) behavior of phosphorus in soils. The immobile nature of phosphorus in soils, compared to nitrogen, and the generally high phosphorus fixation power of soil are discussed; seven factors affecting the fixation of phosphorus by soils are discussed.

347 M MUNICIPAL SEWAGE EFFLUENT FOR IRRIGATION
Beckett, F. E., and C. W. Wilson (ed.)
Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. 169 p.

Descriptors: Water reuse, Water quality data, Conferences.

The realization that sewage effluent is relatively pure water has led to the investigation of its use for irrigation purposes. This report is from a symposium held in Louisiana and the separate articles are abstracted individually.

348 M RIDGE AND FURROW LIQUID WASTE DISPOSAL IN A NORTHERN LATITUDE
Bendixen, T. W., R. D. Hill, W. A. Schwartz, and G. G. Robeck
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 94(SA1): 147-157, February 1968.

Descriptors: Furrow irrigation, Monitoring, Rates of application, Wisconsin, Trickling filter effluent.

The operation and performance of a municipal ridge and furrow liquid waste disposal system in use since 1959 was monitored for a year and a half. One hundred and fifty thousand gallons a day of trickling filter effluent are disposed into the soil via four 1-acre basins. A heavy stand of grass left unharvested over the winter apparently contributes to successful operation. The changes in infiltration rates and quality of the infiltrate with season and under various loading and operating conditions are examined, as are companion field and indoor lysimeter studies comparing various design and operational factors that may influence infiltration protection of groundwater.

349 I CANNERY WASTE TREATMENT BY SPRAY IRRIGATION RUNOFF
Bendixen, T. W., R. D. Hill, F. T. DuByne, and G. G. Robeck
J. Water Pollut. Contr. Fed., 41: 385-391, March 1969.

Descriptors: Food processing wastes, Monitoring, Ohio, Suspended solids, Overland flow.

In 1965, the authors estimate that 2,400 land-waste disposal systems exist in the U.S. with 900 of them serving the food processing industry. In northern Ohio a spray-runoff system for treatment of tomato wastes is described. Operations began in 1954 and monitoring data are available from 1961. In 1964-1965 detailed studies were conducted of infiltration and runoff rates, quality of influent and effluent, effect of storm runoff, and influence of spray waste runoff on stream pollution.

Wastes are sprayed at the top of grassed slopes (5 percent) that are 100 to 200 feet long. The runoff is collected in waterways which in turn discharge to a natural watercourse. During the 1964 and 1965 seasons only 30 to 40 percent of the wastewater appeared as runoff. Removals of COD, total nitrogen, phosphates, and suspended solids, on a mass basis, ranged from 81-95, 73-93, 65-84, and 89-97 percent, respectively.

350 M GROUND WATER NITRATE DISTRIBUTIONS BENEATH FRESNO, CALIFORNIA
Behnke, J. J., and E. E. Haskell, Jr.
J. Amer. Water Works Ass., 60: 477-480, April 1968.

Descriptors: Microbial degradation, Fresno, California, Nitrate contamination, Groundwater recharge.

The occurrence and distribution of nitrates in groundwater is a complex problem dependent upon many variables. Nitrate concentration maps are useful in groundwater studies to indicate areas receiving unusual nitrate concentrations. Nitrate may not be an effective groundwater tracer in all cases, because its concentration in the water table changes markedly with horizontal distance. Areas receiving nitrate concentrations from organic sources should also have high chloride concentrations. Therefore, a comparison of the chloride and nitrate concentrations in the groundwater may offer some insight into the effects of bacterial action on nitrate concentrations. Nitrate concentrations in the uppermost 10 feet of the groundwater body were approximately one-third higher than in deeper waters--below 10 feet the nitrate concentration was essentially uniform with depth.

351 M DISPLACEMENT OF IRON IN SOIL IRRIGATED WITH SEWAGE
Bocko, J.
Zesz. Nauk. Wyzsz. Szk. Roln. Wroclawiu Melior. (Wroclaw, Pol.), 10: 209-217, 1966.

Descriptors: Soil chemical properties, Clogging (soil), Subsurface drainage, Poland.

Decomposition of sewage in soil causes oxygen deficit, resulting in a reduction of Fe^{3+} *and leaching of* Fe^{2+} *to the lower horizons. The displaced Fe accumulates in the lower horizons, forming an impermeable layer, inhibiting water percolation into the drains.*

352 M RETURNING WASTES TO THE LAND, A NEW ROLE FOR AGRICULTURE

Bouwer, H.
J. Soil Water Conserv., 23(5): 164-168, October 1968.

Descriptors: Rates of application, Costs, Tertiary treatment, Groundwater recharge, Phoenix, Arizona.

Land disposal of conventionally treated sewage may be accomplished with (1) high rate systems with renovation as the main objective and application rates of several feet per day (examples: Whittier Narrows, Santee, Flushing Meadows, Dan Region Projects in Israel, and recharge through dunes in Western Holland), (2) low-rate systems for irrigation with application rates of 1 to 4 inches per week, or (3) combination systems for irrigation and renovation such as Melbourne, Penn State project and Bielefeldt, Germany.

The economics of percolations versus coagulation-sedimentation plus carbon adsorption plus disinfection were given. For a 100 mgd plant, advanced waste treatment would cost $37 per acre-ft as compared to $8 per acre-ft for recharge at 300 acre-ft per acre. Also, with groundwater recharge, the water loses its identity as sewage and is collected as "groundwater" whereas the "purified" sewage concept persists with "in-plant" tertiary treatment systems.

353 M GROUND WATER RECHARGE DESIGN FOR RENOVATING WASTE WATER

Bouwer, H.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 96(SA1): 59-74, February 1970.

Descriptors: Arizona, Groundwater recharge, Economic feasibility, Phoenix, Arizona.

Ground water recharge through surface spreading can be an effective and economical method for further treatment or renovation of conventionally treated sewage effluent, cannery wastes, or other low-quality water.

The process could also be used in cases where keeping the waste water out of surface waters is the main consideration. Infiltration of the waste water can be accomplished with recharge basins, ridge-and-furrow systems, or sprinklers. Most of the quality improvement takes place as the fluid percolates through the first few feet of soil, but it is considered desirable to allow the water to travel laterally as ground water for several hundred feet or more before it is collected as reclaimed water by drains or wells. The design of a system of recharge areas with infiltration facilities and of wells or other facilities to collect the reclaimed water must be based on: (1) Keeping the water table beneath the recharge area at sufficient depth to maintain high infiltration rates, sufficient aerobic percolation, and rapid drainage of the soil profile during dryup; (2) allowing sufficient time and distance of underground travel of the reclaimed water; and (3) minimizing spread of the reclaimed water into the aquifer outside the recharge system if contamination is to be avoided. A procedure is presented to predict water-table positions for a system of parallel, rectangular recharge areas, with wells located midway between the areas. This enables the evaluation of the most favorable layout of recharge areas and wells with the desired water table response and travel times. Procedures for obtaining the necessary information on the hydraulic conductivity conditions of the aquifer for recharge systems are presented. Using an analog technique, the horizontal and vertical hydraulic conductivity of an aquifer can be determined from the recharge rate and the water level response in two observation wells of different depths. From the hydraulic conductivity data thus obtained, an effective transmissibility coefficient of the aquifer for recharge can be computed for use in the analysis of a multiple-basin, multiple-well recharge and renovation system. The procedures are illustrated with an evaluation of the hydraulic properties of the aquifer for an experimental recharge system in the Salt River bed west of Phoenix, Arizona, and with a calculation of water table positions and travel times for a system consisting of two parallel recharge strips with wells midway in between.

354 M WATER QUALITY ASPECTS OF INTERMITTENT SYSTEMS USING SECONDARY SEWAGE EFFLUENT

Bouwer, H.

Presented at Artificial Groundwater Recharge Conference, Pap. No. 8, Univ. of Reading, England, September 21-24, 1970. 19 p.

Descriptors: Phoenix, Arizona, Denitrification, Clogging (soil), Spreading basins, Soil physical properties.

Details of the operation of the Flushing Meadows Project near Phoenix, Arizona, are given. Secondary effluent is treated by rapid infiltration in 6 experimental spreading basins. In the spring of 1968 Basin 1 was *left with its original sandy loam, Basin 2 was covered with 2 inches of coarse sand and gravel, and the other 4 basins were seeded to giant bermuda grass. Infiltration rates in the grass-covered basins were 25% higher, and in the gravel-covered basin 50% lower, than in the bare soil basin. Because clogging occurred at or near the soil surface, there was an almost linear relation between the water depth in the basins and the infiltration rate observed.*

With the exception of high nitrate concentrations in the groundwater at the beginning of the inundation cycle (2 weeks' inundation followed by 10 days' drying) the average nitrogen removal after passage through 30 feet of soil was 80%. The nitrogen removal is probably due to denitrification and adsorption of the ammonium to organic material in the soil. More nitrogen was removed under vegetated infiltration basins than non-vegetated basins.

355 M WASTE WATER RECLAMATION

Bur. Sanit. Eng.
Calif. State Dept. Pub. Health, Sacramento, November 1967.

Descriptors: California, Costs, Groundwater recharge, Water quality standards, Surveys.

This compendium of data on reclamation in California includes material on water uses, treatment technology, quality requirements, and costs. Specific chapters deal with wastewater reclamation in the San Francisco Bay Area including present activity and the potential market. Details are presented on the existing 18 reclamation sites in the Bay Area as well as studies on groundwater recharge throughout California.

356 M DETERMINATION OF A COST FOR RECLAIMING SEWAGE EFFLUENT BY GROUND WATER RECHARGE IN PHOENIX, ARIZONA

Buxton, J. L.
Master's Thesis, Arizona State Univ., Phoenix, June 1969.

Descriptors: Phoenix, Arizona, Operation and maintenance, Spreading basins, Costs, Groundwater recharge.

The thesis presents cost estimations for sewage reclamation facilities based upon the model developed by Dr. Bouwer. The reclamation facility consists of an intake system, a spreading system, and a recovery system. The costs estimated include those for capital investment and annual operating and maintenance. The capital costs is amortized at a 6 percent interest rate for projected life spans of 10, 15, and 20 years. The unit cost for the proposed facilities is at $5 to $6 per acre foot of recharged and reclaiming water in the Phoenix area.

357 M A TECHNICAL AND ECONOMIC FEASIBILITY STUDY OF THE USE OF MUNICIPAL SEWAGE EFFLUENT FOR IRRIGATION

Cantrell, R. P., Charles W. Wilson, F. E. Beckett, and F. A. Calvo
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 135-157.

Descriptors: Economic feasibility, Sprinkler irrigation, Louisiana, Furrow irrigation, Salinity.

This is a study investigating the technical aspects of using sewage effluents for irrigation. The study, conducted at the City of Ruston, Louisiana, concluded that sewage effluent from the Ruston sewage treatment plants could be used for irrigation without causing significant technical problems. The problem of corrosion and sprinkler nozzle plugging were not expected to be of any concern. The harmful effects of salts and chemicals in the effluent were expected to be negligible.

Sewage effluent from Ruston sewage treatment plants could be used for irrigation of field crops and pasture. However, sprinkler irrigation of fruits and vegetables to be eaten raw was not advisable. The effluent could be used to furrow irrigate fruit trees, as long as the fruit did not come into contact with the effluent.

The cost of developing sewage effluent streams for irrigation water compares favorably with other sources of water. For the Lincoln Parrish farms studied, the average annual fixed and operating cost for the sewage effluent systems was $54.82 per acre, as compared to $105.87 per acre when using deep wells as a source of water. The cost shown for the sewage effluent systems did not include the fertilizer value of the effluent.

358 M HEALTH REGULATIONS CONCERNING SEWAGE EFFLUENT FOR IRRIGATION

Coerver, J. F.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 123-133.

Descriptors: Planning, Sprinkler irrigation, Vegetable crops, Public health regulations.

The author investigated and discussed health regulations regarding sewage irrigation with particular emphasis on practical aspects. A summary of questionnaires from State Health Departments on sewage irrigation was presented. The author concluded that regulations on the use of municipal sewage effluent for irrigation vary from state to state. Any plans to use municipal sewage for irrigation should begin with an informal proposal to the State Health Department for preliminary appraisal, preferably before any expensive plans are formulated. The use of untreated sewage for irrigation is generally prohibited. States approve the use of treated sewage for irrigation except in the more hazardous situations involving vegetables eaten raw, public access lawns, and dairy pastures, etc., although some states recognize that sewage can be reclaimed by extensive treatment to satisfactorily reduce hazards.

359 M EFFECTS ON VEGETABLES OF IRRIGATION WITH WASTE TREATMENT EFFLUENTS AND POSSIBLE PLANT PATHOGEN

Cole, H., et al.
Phytopathology, 59: 1151-1191, September 1969.

Descriptors: Plant diseases, Soil microbiology, Reviews.

Using an extensive literature search, the authors make a thorough investigation on the research done on plant pathogens as related to effluent reuse. Although in many cases, the use of effluent is similar in effect to pure water irrigation, research is still badly needed, especially in humid regions where plant pathogens are already present and active in the soil.

360 S LIQUID SLUDGE AS A FARM FERTILIZER

Conn, R. L.
Compost Sci., 11(3): 24-25, May-June 1970.

Descriptors: Chicago, Illinois, Rates of application, Economic feasibility, Anaerobic digestion, Recycling nutrients.

The University of Illinois' Depts. of Agronomy and Civil Engineering are working on a three-year project to study the fertilizer value and application of digested liquid sludge to farmland. The research plots used in the study will try to determine the method and maximum rate of sludge application possible before bad effects appear.

(Also appears in Crops and Soils Magazine, 22(4): 12-13, 1970.)

361 M MIGRATION OF POLLUTANTS IN A GLACIAL OUTWASH ENVIRONMENT

Crosby, J. W., D. L. Johnstone, C. H. Drake, and R. L. Fenton
Water Resour. Res., 4(5): 1095-1114, October 1968.

Descriptors: Washington, Groundwater contamination, Soil physical properties, Groundwater movement, Septic tanks.

Soil samples were taken from test holes to determine the movement of polluting chemicals and bacteria in the alluvial soil of the Spokane River valley, Washington, caused by soil disposal of septic tank effluent from a nursing home. It was found that bacteria were normally removed after passage through 20 ft of soil; that moisture fronts moved further, laterally and vertically, in the winter; and that chlorides and nitrates moved at rates comparable to those of the dispersing effluents. Detailed observations of moisture distribution were supplemented by observations using sand models, and it was demonstrated that dry conditions at depth were caused by lateral dispersion by capillarity.

362 M WASTEWATER RECLAMATION AND EXPORT AT SOUTH TAHOE

Culp, Russell, and Harlan Moyer
Civil Eng., 39: 38-42, June 1969.

Descriptors: Sprinkler irrigation, Tertiary treatment, Oxidation lagoons, California.

The spraying of effluent on land was discontinued and now the effluent is processed by tertiary treatment and then stored in a basin for use in irrigation.

363 S RECLAIMING LAND WITH CHICAGO SEWAGE SLUDGE

Dalton, F. E.
Compost Sci., 8(2): 5-8, December 1968.

Descriptors: Chicago, Illinois, Planning, Land reclamation, Sludge disposal.

This article describes present methods of sludge disposal and plans for construction of a ten-acre small-scale farm irrigation system for crop utilization of digested sludge.

364 M TUCSON WASTEWATER RECLAMATION PROJECT
Davis, G. E., and J. F. Stafford
Tucson Wastewater Reclamation Project, Water and Sewers Dept., Univ. of Arizona, Tucson, First Annual Report, July 1966.

Descriptors: Tucson, Arizona, Public acceptance, Viruses, Water reuse, Wastewater treatment.

A summary of the first year of the Tucson Wastewater Reclamation Project. The primary purpose of the project is to demonstrate the chemical, microbiological, and virological safety and aesthetic acceptability of including wastewater, which has been renovated by use of a soil system, as a dependable and substantial portion of the future water supply for metropolitan Tucson.

365 S ULTIMATE DISPOSAL OF WASTE WATER CONCENTRATES TO THE ENVIRONMENT
Dean, Robert B.
Environ. Sci. Technol., 2: 1079-1086, December 1968.

Descriptors: Wastewater treatment, Sludge disposal.

Advanced treatment of wastewater is basically the separation of a valuable product--water--from its pollutants. The residue of substances which remains normally has no positive economic value, and must be degraded or disposed of. In this respect, waste treatment is similar to other industrial processing: separating the wheat from the chaff, copper from its gangue, or wood pulp from lignin. These low value residues, like those from wastewater treatment, are usually an economic liability and may become a pollutant. It is the assignment of the Ultimate Disposal Research Activity of the Federal Water Pollution Control Administration to devise methods for treating these residues so that they will not pollute the environment.

366 M PUBLIC HEALTH AND WATER RECLAMATION
Deaner, D. G.
Water Sewage Works, Reference Number, 117: R7-R13, 1970.

Descriptors: Public health regulations, California, Water quality data, Reviews, Surveys.

A 1969 directory of reclamation systems listed 170 systems in California. This article reports on 45 of the systems that were selected for an intensified surveillance program. The objectives of the program were to establish the status of public health and safety provisions and to develop information for establishing reliability criteria at reclamation operations.

367 M REVIEW OF LITERATURE ON IRRIGATION OF HUMAN FOOD CROPS WITH WATERS CONTAINING VARIOUS AMOUNTS OF DOMESTIC WASTEWATERS

Dinges, W. R.
Texas State Dept. Health, Div. of Wastewater Technology and Surveillance, San Antonio, 1969. 31 p. (Unpublished)

Descriptors: Reviews, Public health regulations, Texas, Pathogenic bacteria, Human diseases.

Definitive epidemiological information about the transmission of diseases by consumption of foods irrigated with contaminated water is, essentially, nonexistent. A search of the literature did not reveal studies made on irrigation of food crops with treated and disinfected sewage treatment plant effluents. Most investigators were of the opinion that disease-causing organisms, with the possible exception of Ascaris lumbercoides (eggs) and tubercule bacteria (spores), die rapidly (2-30 days) under field conditions. The efforts at establishment of realistic sanitary standards for irrigation waters by public health authorities have suffered due to a paucity of reliable information.

368 M VIRUS MOVEMENT IN GROUNDWATER

Drewry, W. A., and R. Eliassen
J. Water Pollut. Contr. Fed., 40:R257-R271, August 1968.

Descriptors: Soil chemical properties, Groundwater contamination, Viruses, Groundwater movement.

Virus retention by soils is studied. The adsorption of virus by soils is greatly affected by the pH of the water-soil system. At lower pH values it was found that adsorption was faster. Virus adsorption by some soils can be greatly enhanced by increasing the cation concentration of the liquid phase of a soil-water system. It was concluded that virus movement through soils under saturated conditions should present no great health hazard with respect to underground water supplies.

369 M ASSESSMENT OF THE EFFECTIVENESS AND EFFECTS OF LAND DISPOSAL METHODOLOGIES OF WASTEWATER MANAGEMENT

Driver, C. H., et al.
U.S. Army Corps Eng., Washington, D.C., Wastewater Management Report 72-1, January 1972. 147 p.

Descriptors: Overland flow, Wastewater treatment, Reviews, Sprinkler irrigation.

Land disposal is categorized as (1) spray irrigation, (2) rapid infiltration ponds, and (3) overland runoff. Criteria are given in terms of loadings, soils, slopes, and management practices for each category.

Specific descriptions are given for hydrologic, water quality, and soil characteristics in California, the Great Lakes States, and New England. Literature reviews are also included for microorganism removal in soil, BOD removal mechanisms, indigenous soil pathogens, chemical interaction of soil and wastewater, and impacts of treatment wastewater. Impacts discussed include those on climate, soil, and groundwater. No cost information is included.

370 M SURVIVAL OF PATHOGENS AND RELATED DISEASE HAZARDS

Dunlop, S. G.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 107-122.

Descriptors: Reviews, Viruses, Human diseases, Pathogenic bacteria.

The author reviewed the literature related to the survival of microorganisms on irrigated crops and in the soil. The probability that microorganisms will survive in treated effluent is high and varies with the type of microorganism. Normally the microorganisms include a large variety of bacteria, spirochetes, protozoa, helminths and viruses which originate from municipal and industrial wastes. Diseases associated with these organisms include Salmonella gastroenteritis, typhoid and paratyphoid fevers, bacillary and amoebic dysentery, choloera vibriosis, leptospirosis and infectious hepatitis. Less commonly seen are tuberculosis, brucellosis, listeriosis, coccidiosis, swine erysipelas, ascariasis, cysticerosis and tapeworm disease, fascioliasis, and schistosomiasis.

371 M WASTEWATER RECLAMATION PROJECT
Dye, E. O.
Water Sewage Works, 115: 139-144, April 1968.

Descriptors: Tucson, Arizona, Activated sludge effluents, Costs, Wastewater treatment, Reviews.

The city of Tucson is interested in wastewater reclamation, with approval by health authorities. The second year of the Tucson Wastewater Reclamation Project embodied a program of intensive sampling and analysis of applied activated sludge effluent, intrafilter aliquots representing progressive stages of renovation, and the end products. Two phases of application were completed and critically reviewed, leading to the beginning of a third. Costs were discussed.

372 M MUNICIPAL WASTEWATER REUSE FOR IRRIGATION
Eastman, P. W., Jr.
Amer. Soc. Civil Eng., J. Irrigation Drainage Div., 93(IR3): 25-31, September 1967.

Descriptors: Public health regulations, Water reuse, Southwest U.S.

The demand for reuse of wastewater is discussed with a projection of water needs to the year 2000. States using sewage applied to land, with estimated population served, are described. California and Texas are two states used as examples for sewage irrigation. Health aspects of sewage irrigation are studied in detail, with references to other countries.

373 I SPRAY IRRIGATION
Eckenfelder, W. Wesley, Jr.
In: Industrial Water Pollution Control, New York, McGraw-Hill Book Co., 1966. p. 257-261.

Descriptors: Food processing wastes, Pulp and paper wastes, Tannery wastes, Dairy wastes.

Spray irrigation is one of three irrigation methods of disposing of liquid wastes. Factors governing irrigation include initial soil moisture, character of the soil, depth to groundwater, stratification of the soil, and ground cover and terrain. Wastes successfully irrigated by spray irrigation include cannery, pulp and paper, dairy, tannery, sulfite and boxboard.

374 M STUDIES ON THE MOVEMENT OF VIRUSES WITH GROUNDWATER

Eliassen, R., et al.
Water Quality Control Research Laboratory, Stanford Univ., Palo Alto,
California, 1967.

Descriptors: Soil types, Soil physical properties, Groundwater movement, California, Viruses.

Tracers and analytical techniques were developed for bacterial viruses and their movement through five soils and seven uniform sands under saturated flow conditions was studied. These studies produced the following important conclusions:

1. The removal of virus from percolating water is largely due to sorption on the soil particles.

2. Soils having a higher clay content adsorb viruses more rapidly than those with less clay. The retention capacity for 3 soils, having clay contents ranging from 37% to 5%, were all on the order of 10^{10} viruses per gram, and for sand with flow rates of 6 to 7 ft per day, the retention capacity was on the order of 10^{8} viruses per gram. As the pH increased above 7 the fraction of viruses adsorbed decreased markedly. As the cation concentration in the water increased, the fraction of viruses adsorbed also increased.

There is no theory for describing the movement of viruses through soil, but the knowledge that adsorption is the important removal mechanism provides a qualitative description. It indicates that prolonged application of high concentration of viruses to even clay soils will eventually result in a breakthrough of organisms.

375 S USING SEWAGE SLUDGE ON FARMLAND

Evans, James O.
Compost Sci., 9(2): 16-17, June 1968.

Descriptors: Pennsylvania, Recycling nutrients, Sludge disposal.

Digested sewage sludge gets big demand after Pennsylvania farmers take a look at results of applications to fields.

376 M UTILIZATION OF SEWAGE FOR AGRICULTURAL PURPOSES
Feinmesser, A., and S. Z. Hershkovitz
Water Sewage Works, 114: 181-184, May 1967.

Descriptors: Detergents, Odor, Salinity, Heavy metals.

The use of sewage for irrigation is important for three reasons: (1) re-utilization of a source of water; (2) utilization of the fertilizer present in sewage; (3) inexpensive and efficient solution of the problems of sanitary disposal and prevention of possible sanitary nuisances by sewage. Problems occur from the salts, toxic materials and boron present in sewage, the latter often from detergents.

377 M SOME INVESTIGATIONS OF TERTIARY METHODS OF TREATMENT
Fish, H. H.
J. Inst. Pub. Health Eng. (London), 65: 33-47, 1966.

Descriptors: Oxidation lagoons, Suspended solids, England, Costs, Tertiary treatment.

Tertiary treatment of sewage-works effluents in Essex by irrigation on grass plots, slow sand filtration, microstraining, and lagooning has been studied over a period of 12 months, covering removal of BOD and suspended solids, and of nominal oxygen belance of the effluent; some of the results obtained by lagooning were superior. All four processes produced similar results when treating humus tank effluent, conforming to the Royal Commission standard. The costs of the processes are compared and their merits are considered in relation to requirements of river authorities, sewerage authorities, and public health protection.

In reply to a question raised in discussion, the author stated that these processes caused only slight reduction in the concentration of anionic detergents.

378 S THE EFFECT OF SEWAGE, OVERLYING LIQUOR AND COMPOSTING ON THE VIABILITY OF PARASITE, REPRODUCTIVE STATES
Forstner, M. J.
Wasser Abwasser Forschung (Munich), 3: 176-184, 1970.

Descriptors: Human diseases, Sludge disposal, Anaerobic digestion, Sprinkler irrigation, Europe.

Detailed parasitological tests have been carried out to study the distribution, viability and rate of secondary infection caused by worm ova in cattle and agriculture originating from fields irrigated with silage or sewage as artificial rain. Results showed that sewage sludge containing parasites and ova was rendered harmless after composting for two or three months or after pasturization.

379 M RATIONALE OF STANDARDS FOR USE OF RECLAIMED WATER

Foster, H. B., Jr., and W. F. Jopling
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 95(SA3): 503-514, 1969.

Descriptors: California, Recreational facilities, Wastewater treatment, Public health regulations, Water quality standards.

Committees developed workable standards for safely utilizing reclaimed wastewater in California. Applications such as irrigation of crops and parks, and recreational impoundments were developed. In the development of the standards, the major controversy centered around four basic subjects:

1. *Sampling and analysis requirements for adequate disinfection;*
2. *Specification of proper practices in the production and use of reclaimed wastewater;*
3. *Use of descriptive terms versus specific quality parameters in definitions;*
4. *Quality requirements for specific uses.*

380 M ECONOMICS OF ARTIFICIAL RECHARGE FOR MUNICIPAL WATER SUPPLY

Frankel, R. J.
Resources for the Future, Inc., Washington, D.C., Artificial Recharge and Management of Aquifers, Symp. of Haifa (March 19-26, 1967), Int. Ass. Sci. Hydrology Publ. No. 72, 1967. p. 289-301.

Descriptors: Groundwater recharge, Economic feasibility, Costs, Wastewater treatment.

A research project was undertaken to determine whether or not waste reclamation could be economically competitive with other water sources *for municipal water supply. Numerous advanced waste treatment systems and recycle schemes were evaluated. Wastewater renovation through groundwater recharge proved to be the most feasible solution to reclamation of the effluent of any type treatment plant today. Further study has evaluated the chemical and physical limitations of artificial recharge, using municipal wastes; and the economic trade-offs between additional treatment prior to recharge and greater land utilization and the break-even point for land values as a function of economics of scale. Finally the economics of a particular case study in the arid West of the United States is discussed as well as proposed scheme for converting the nation's capital, Washington, D.C., in the humid East from using solely surface water supplies to using artifical recharge of undeveloped aquifers for future expansion of water supplies.*

381 I EXPERIENCES OF CANNERY AND POULTRY WASTE TREATMENT OPERATIONS

Gilde, L. C.
In: Proc. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1967. p. 675-686.

Descriptors: Food processing wastes, Overland flow, Oxidation lagoons, Design data, Paris, Texas.

Five locations of land disposal of wastewater for cannery and poultry operations by Campbell Soup Company are selected and described in detail. Three spray irrigation and two lagoon systems are presented. The design criteria and the removal efficiencies of each system are presented. The three spray sites include two overland flow systems--Paris, Texas and Napoleon, Ohio--and an underdrained spray irrigation site at Sumpter, S.C.

Campbell Soup Company has adopted a policy of building plants in rural areas. The selection of plant site depends mainly upon the source of water supply and the capability of waste treatment. Due to differences of environment from site to site, none of the plants are utilizing the same system. As a result, the efficiency of each system is different.

382 I FOOD PROCESSING WASTE TREATMENT BY SURFACE INFILTRATION

Gilde, Louis
In: Proc. 1st Nat. Symp. Food Processing Wastes, Portland, Ore., Fed. Water Quality Admn., Report No. 12060---04/70, 1970. p. 311-326.

Descriptors: Overland flow, Food processing wastes, Paris, Texas, Rates of application, Water quality data.

A spray irrigation system using overland flow has been successfully operated by the Campbell Soup Company at Paris, Texas, obtaining removal rates of 98 percent for suspended solids, 99 percent for BOD, 92 percent for total nitrogen and 62 percent for total phosphorus. Rates of application were from 0.25-0.50 inch per day to land with a slope of 1-12 percent and a length of 200-300 feet. Grass cover was reed canary and 61 percent of all water applied (wastewater and rainfall) ran off the land.

383 M SIGNIFICANCE OF ESCHERICHIA COLI SEROTYPIS IN WASTEWATER EFFLUENT
Glantz, Paul, and Thomas Jacks
J. Water Pollut. Contr. Fed., 39: 1918-1921, November 1967.

Descriptors: Coliforms, Sprinkler irrigation, Rates of application, Soil contamination.

Sewage effluents with average coliform densities of 2,000/100 ml of chlorinated effluent were sprayed over a field at rates of one and two inches per week. Coliform counts at 2 and 4 feet below the surface gave average readings of 1/100 ml, indicating a satisfactory purification by the soil. Birds native to the area were also tested and found to have suffered no contamination from the spraying operation.

384 S TRANSPORTING WASTES TO BUILD SOILS
Goldstein, Jerome
Compost Sci., 11(5): 22-24, September-October 1970.

Descriptors: Chicago, Illinois, Economic feasibility, Sludge disposal.

Chicago proves it's cheaper to move sludge to farms than to burn it.

385 M PRACTICAL IRRIGATION WITH SEWAGE EFFLUENT
Gray, J. F.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 49-56.

Descriptors: Lubbock, Texas, Rates of application, Groundwater recharge, Water management (applied), Grain crops.

The author described the application of sewage effluent for irrigation from the sewage treatment plant at Lubbock, Texas. The system irrigated the area of 2,900 acres at a rate of 14.5 to 15 mgd. Many crops were grown under such conditions. The comparison of economic benefit was estimated as follows: Under Lubbock climatic and soil conditions, the expected yields were 800 to 1,000 pounds of grain sorghums, 10 to 12 bushels of wheat, or 150 to 225 pounds of lint cotton per acre without the use of irrigation water. Under good management the expected yields of these crops under irrigation would be 4,000 to 5,000 pounds of grain sorghums, 39 to 40 bushels of wheat, and 600 to 800 pounds of lint cotton. By using effluent, yields run as high as 2.5 bales per acre on cotton, approximately 6,500 pounds of grain sorghum and close to 80 bushels of wheat without commercial fertilizer.

The author found that effluent irrigation, both heavy and moderate, has been highly successful from the standpoint of increasing crop yields, preventing pollution, improving soil conditions, and recharging the underground aquifer.

386 M ELIMINATION OF VIRUSES FROM SEWAGE IN EXPERIMENTAL UNDERGROUND FILTRATION

Grigor'Eva, L. V., and E. I. Goncharuk
Hyg. Sanit. (USSR), 31(10-12): 158-163, October 1966.

Descriptors: Coliforms, Rates of application, Subsurface drainage, Soviet Union, Viruses.

Laboratory models of underground filtration beds and filtering wells have been constructed to investigate the danger of bacterial contamination of sewage. Two Coxsackie strains, A5 and A14, and E. coli No. 163 were used to test the sewage.

The sewage load was 301/24 hr per 1 running meter for underground filtration beds and 1,801/24 hr per 1 m^2 for the filtering wells. The application of sewage continued for 42 days.

The results showed that the purification of viruses and bacteria was more satisfactory in the case of the underground filtration beds than in the case of filtering wells. After application in the period of maturation, Coxsackie A viruses and E. coli were more frequently detected in the concentrated filtrate but only until the 20th day. The underground filtration let through 0.002 to 0.042 percent of the initial bacteriophage, while the filtering well let through 0.007 to 0.109 percent.

387 I CURRENT PRACTICE IN POTATO PROCESSING WASTE TREATMENT

Guttormsen, Kristian, and Dale Carlson
U.S. Dept. Interior, Corvallis, Ore., Fed. Water Pollut. Contr. Admn.
Report No. DAST-14, October 1969. 108 p.

Descriptors: Potato processing wastes, Sprinkler irrigation, Rates of application, Food processing wastes.

Pages 69-72 of this report described current successful spray irrigation systems for potato processing wastes and vegetable wastes. Rates of one million gallons per year for 3.5 acres are reported.

388 I SPRAY IRRIGATION TREATMENT

Haas, F. C.
In: Proc. Symp. Potato Waste Treat., Univ. of Idaho, Moscow, Idaho, Fed. Water Pollut. Contr. Admn., Report No. 12060---, July 1968. p. 55-59.

Descriptors: Washington, Potato processing wastes, Rates of application, Operation and maintenance, Costs.

The American Potato Company near Moses Lake, Washington, has been using spray irrigation to dispose of its wastes since 1965. Total waste flow of 1.2 mgd is sprayed on 120 acres at an average application rate of 0.35 in. per day. Initial capital cost excluding land was $30,000 and total operating costs are $40,000 per year.

389 M CHEMICAL INTERACTIONS OF WASTEWATER IN A SOIL ENVIRONMENT

Hajek, B. F.
J. Water Pollut. Contr. Fed., 41: 1775-1786, October 1969.

Descriptors: Wastewater disposal, Soil chemical properties, Soil physical properties, Alabama.

The effects of wastewater disposal to soil will be scrutinized increasingly to predict the assimilative capacity of soil. One phase of wastewater disposal to soil, that of chemically contaminated wastewater has been discussed to acquaint environmental engineers and scientists with experimental methods presently available for making such a prediction. These methods are wastewater chemical characterization, and chemical interactions of soil-waste systems.

390 M UTILIZATION OF SEWAGE FOR AGRICULTURAL PURPOSES

Hershkovitz, S. Z, and A. Feinmesser
Water Sewage Works, 114: 181-184, May 1967.

Descriptors: Oxidation lagoons, Economic feasibility, Wastewater treatment, Israel.

The re-utilization of sewage is included as part of the water potential in Israel and is estimated at about 40 bil gal. per annum, or about 10 percent of the total potential of the country. The utilization of an additional source of water, the utilization of sewage for agricultural purposes is important for the re-utilization of an additional source of water, the utilization of fertilizers present in the sewage, and as an inexpensive and efficient solution of the problems of sanitary disposal. The use of sewage for irrigation in an efficient manner can increase crop yields. Oxidation ponds are the most suitable purification means in Israel.

391 S DIGESTED SLUDGE DISPOSAL ON CROP LAND

Hinesly, T. D., and Ben Sosewitz
J. Water Pollut. Contr. Fed., 41: 822-830, May 1969.

Descriptors: Odor, Chicago, Illinois, Groundwater contamination, Costs, Heavy metals.

The Metropolitan Sanitary District of Greater Chicago concluded that digestion followed by land disposal could cope with Chicago's 1,000 tons (907,000kg)/day of sludge successfully at a cost of $20 to $23/ton ($0.022 to $0.025/kg). Research designed to determine groundwater contamination, the effect of heavy metals, and crop irrigation parameters was conducted by the University of Illinois and the District. Kenaf and corn were used as the experimental vegetables. An 8-acre (3.2-ha) and a 30-acre (12.2-ha) plot were used for the tests. Crops responded favorably to digested sludge; odors and flies were not problems; and nitrate rates in drainage waters increased.

392 M IRRIGATION WITH RECLAIMED WASTE WATER

Hirsch, L.
Water Wastes Eng., 6: 58-60, April 1969.

Descriptors: Salinity, Water quality standards, Soil physical properties, Heavy metals.

Salinity, boron, lithium, and sodium are specific indicators of irrigation water quality. The allowable concentrations are determined by many factors, the more significant of which include soil permeability, irrigation practices, and plant selectivity.

393 M WASTE WATER RENOVATION BY THE LAND--A LIVING FILTER

Kardos, L. T.
In: Agr. and the Quality of Our Environ., Amer. Ass. for Advancement of Sci., Washington, D.C., Amer. Ass. for Advancement of Sci. Publ. 85, 1967. p. 241-250.

Descriptors: Penn State, Pennsylvania, Rates of application, Soil types, Groundwater recharge, Design data.

The 4-year Penn State Project was designed to reclaim wastewater by the land, using a "living filter" system. The soil ranged in surface texture from silt loam to silty clay loam, with slopes averaging four percent. Each irrigation area was 240 ft wide and 800 ft long, and the crops were grown in a strip arrangement in a rotation sequence. The rate of application of effluent in 1963 was 0.64 in./hr; 1 in./wk and 2 in./wk were applied. In 1964 and 1965, the rate was 0.25 in./hr. The fertilizer equivalent of the wastewater at the 2 in./wk level was equal to that of 2,000 lbs of 7-12-11 fertilizer/acre in 1963; and 2,000 lbs of 14-15-14 fertilizer in 1964; and 2,000 lbs of 5-10-5 fertilizer in 1965. The crops were harvested and subsamples were analyzed for nitrogen, phosphorous, potassium, calcium, magnesium, etc. Soil water samples were taken by means of suction lysimeters. Since the beginning of the project the area has been under severe drought conditions; however, hay yields were increased 139 percent, corn silage 39 percent, corn grain 78 percent, and oats grain 70 percent. The phosphorous and potassium concentrations in the alfalfa were 63 percent and 35 percent higher in the effluent-treated plots than the control plots, while at the same time the quantities removed were 300 percent and 224 percent higher. At the 1 in./wk level, corn silage removed 200 percent total N, 39 percent P, and 62 percent K. The microbes also degrade the complex organic molecules. After three years of operation, water samples showed that the renovation capacity of the soil profile was still excellent. The growing crop prevents the breakthrough of excessively large amounts of nitrate nitrogen. The "living filter" also recharges the water table by about 80 percent of the effluent applied to the land.

394 M CROP RESPONSE TO SEWAGE EFFLUENT

Kardos, L. T.

In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 21-29.

Descriptors: Nutrient removal, Penn State, Pennsylvania, Rates of application, Forage crops, Grain crops.

This is a report of experimental work done at Penn State University during 1964 and 1967. An objective of the experiment was to find the effect of sewage effluent on the yield of agronomic crops, and the tests included (1) crop yield at various levels of application of wastewater, (2) nutrients removed in harvested crops as percentage of nutrients applied in the wastewater. The specific crops studied were alfalfa hay and corn silage in relation to the wastewater constituents, nitrogen, phosphorus and potassium.

395 S A SOLUTION TO THE SLUDGE PROBLEM AT THE SEWAGE WORKS OF MUNICH

Karnovsky, F.

Muenchner Beitr. Abwasser-Fisch.-Flussbiol. (Munich), 13: 211-225, 1966.

Descriptors: Sludge disposal, Munich, Germany.

The author discusses the utilization and disposal of domestic and industrial sludges in relation to recent developments at the Munich sewage works. Details are given of sludge drying in beds followed by removal with sludge dredgers.

396 S THE UTILIZATION OF SEWAGE SLUDGE IN MUNICH

Karnovsky, F.

Gas- Wasserfach (Munich), 107(34): 962-964, August 1966.

Descriptors: Sludge disposal, Munich, Germany, Recycling nutrients.

Further reference is made to the disposal and utilization of sewage sludge in connection with the successful operation of the sludge-digestive plant at Munich-Graslappen and to the increasing use of sewage sludge in agriculture.

397 M THE MOVEMENT OF DISEASE PRODUCING ORGANISMS THROUGH SOILS

Krone, R. B.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 75-105.

Descriptors: Viruses, Pathogenic bacteria, Aerobic conditions, Human diseases.

Data were given on the character of disease organisms, the processes of filtration in soil, and the experiences of wastewater application for irrigation. The conclusions drawn by the author include:

1. *Pathogens have a wide variety of physical and biological characteristics, including wide ranges of size, shape, surface properties and die away rates.*
2. *Straining the pathogens at the soil surface and absorption of viruses near the soil surface is desirable because it limits travel of pathogens most. It is also subject to wide variations in temperature and moisture and is most likely to remain in an aerobic condition. A soil containing clay should therefore be used for irrigation with treated sewage.*
3. *Wide experience in irrigation with treated sewage indicates that it is safe provided that at least primary treatment is used, and provided that the crops are not consumed directly by humans. Secondary treatment and chlorination is recommended for aesthetic reasons.*

398 M INFLUENCE OF LYUBERTSY FILTRATION BEDS UPON SUB-SURFACE WATERS

Kudryavtseva, B. M.
Hyg. Sanit. (USSR), 33(1-3): 271-274, January-March 1968.

Descriptors: Groundwater contamination, Coliforms, Groundwater movement, Spreading basins, Soviet Union.

The Lyubertsy filtration beds are in an area where artesian waters are extensively used for water supply. The beds are situated on a plain. The geological structure of the area shows that the groundwaters occur *in Quaternary sands at a depth of about 1 m. The artesian waters occur in Upper, Middle, and Lower Carboniferous fissured limestones. The principal confining layer is formed by Upper Jurasic clays.*

The sewage received by the filtration beds has the usual composition of household-fecal sewage. Twenty-six bore holes were drilled for studies of groundwaters around the filtration beds. Groundwaters from bore holes near the beds had a high concentration of ammonia (4 mg/l), chlorides (85 mg/l), sulfates (105 mg/l) and dry residue (500 mg/l), as against 0.5 mg/l ammonia, 15 mg/l chlorides, 40 mg/l sulfates, and 180 mg/l dry residue in the water of a control bore hole. The coli index of the groundwaters decreases from 500 at a distance of 5 m from the filter to 5 at a distance of 125 m, their progress over this distance taking approximately 300 days. Over the same period, the concentration of ammonia nitrogen decreased from 4 to 0.5 mg/l, oxidizability from 10 to 5 mg/l, etc. The concentration of chlorides in the flow of groundwater increased with increasing distance, from 85 to 127 mg/l, their concentration in the sewage being at the level of 50-60 mg/l during the last two years.

399 M PURIFICATION OF EFFLUENT WATER BY SOILS

Kutepov, L. E.
Pochvovedenie (Moscow), p. 57-69, November 1968.

Descriptors: Reviews, Wastewater treatment, Soviet Union.

A review with 55 references. Fields irrigated with effluent can be used as independent purification systems or can be combined with artificial biological purification systems.

400 M INFLUENCE OF DOMESTIC WASTEWATER PRETREATMENT ON SOIL CLOGGING

Laak, R.
J. Water Pollut. Contr. Fed., 42: 1495-1500, August 1970.

Descriptors: Soil types, Aerated lagoon effluents, Clogging (soil), Septic tanks, United States.

Increased pretreatment of domestic wastewater prior to soil surface application resulted in reducing the clogging rate of the soil surface. A laboratory study with 30 soil columns, three different soils, and septic tank and extended aeration effluent was carried out. The soils were intermittently loaded with the effluent up to clogging failure, which was reached within 180 days. The service time of the soil surfaces was increased when the *concentrations of TSS and BOD in the hydraulic load were decreased. The clogging material consisted of about 90 percent bacterial cells with only traces of iron and sulfate.*

401 S AGRICULTURAL UTILIZATION OF SEWAGE EFFLUENT AND SLUDGE--AN ANNOTATED BIBLIOGRAPHY
Law, J. P.
U.S. Dept. Interior, Washington, D.C., Fed. Water Pollut. Contr. Admn., Report No. CWR-2, January 1968. 89 p.

Descriptors: Reviews, Bibliographies, Recreational facilities, Public health regulations.

An excellent reference source, this book contains over 200 references and reviews of articles pertaining to effluent utilization for agriculture, industry, recreational purposes and other uses. Included are sections on sanitary aspects of wastewater utilization, effects of effluents on soil properties, and pollution abatement. Period covered is from before 1951 to 1965.

402 M NUTRIENT REMOVAL FROM ENRICHED WASTE EFFLUENT BY THE HYDROPONIC CULTURE OF COOL SEASON GRASSES
Law, J. P.
U.S. Dept. Interior, Ada, Ok., Fed. Water Pollut. Contr. Admn., Report No. 16080 10/69, October 1969. 33 p.

Descriptors: Nutrient removal, Hydroponics, Trickling filter effluent, Phosphorus removal.

Tall fescue and perennial ryegrass were grown in hydroponic culture tanks to evaluate their nutrient removal capabilities when supplied with secondary sewage effluent. Six tanks were filled with a 15 in. bed of pea gravel covered with a 2 in. layer of coarse sand. Trickling filter effluent passed through the 20 ft long tanks with detention times of 1 and 2 days. No grass was planted in the 2 control tanks where total nitrogen removal was 56% and phosphorus removal was 5%. With grass growth nitrogen removal increased to 78% and phosphorus removal increased to 13%. However, only 3-7% of the increased 22% nitrogen removal was accounted for in the grass harvest.

Fescue yields were 10 tons per acre with a nitrogen uptake of 330 lb/acre/yr. Ryegrass, which went dormant in mid-summer, produced 6-7 tons per acre with nitrogen uptakes of 180-220 lb/acre/yr. Phosphorus uptakes for ryegrass were 56-68 lb/acre/yr and for fescue were 100 lg/acre/yr. BOD removal was about 85% in tall tanks.

403 I NUTRIENT REMOVAL FROM CANNERY WASTES BY SPRAY IRRIGATION OF GRASSLAND

Law, J. P., Jr., R. E. Thomas, and L. H. Myers
U.S. Dept. Interior, Ada, Ok., Fed. Water Pollut. Contr. Admn. Report No. 16080 11/69, November 1969. 73 p.

Descriptors: Nutrient removal, Paris, Texas, Food processing wastes, Phosphorus removal, Overland flow.

A 12-month study was conducted of the overland flow land treatment system for Campbell Soup Co. at Paris, Texas, from April 1968 to April 1969. Under its present operating schedule, the system achieves mass removals of 86 to 93 percent total nitrogen and 50 to 65 percent phosphorus. During the study, the experimental areas received 133 inches of wastewater during 43 weeks of spraying and the annual rainfall was 57 inches.

Evaluation of surface and subsoil samples and soil water at the 3-ft depth indicated an increase in salinity with age, but nitrogen and phosphorus remained low. Much of the phosphorus removed from the wastewater was found on the surface soil layer.

404 I CANNERY WASTEWATER TREATMENT BY HIGH-RATE SPRAY ON GRASSLAND

Law, James, Jr., Richard Thomas, and Leon Myers
J. Water Pollut. Contr. Fed., 42: 1621-1623, September 1970.

Descriptors: Food processing wastes, Soil types, Overland flow, Paris, Texas, Water quality data.

At an operating cost of about five cents/1,000 gallons, the Campbell Soup Company in Paris, Texas disposes of 3.6 mgd of cannery wastes by spray irrigation to grassland crops. Pretreatment consists of screening on 10-mesh screens. The soil varies in type from sandy loam to clay loam. Results have been very good. Phosphorus removal is as high as 88 percent; nitrogen removal as high as 90 percent; and volatile solids removal as high as 99 percent. BOD removal is about 98 percent. Of a total of 133 inches of water applied, 60 percent returned as runoff to streams.

405 M SOIL AND GRASS FILTRATION OF DOMESTIC SEWAGE EFFLUENT FOR THE REMOVAL OF TRACE ELEMENTS

Lehman, G. S.
Thesis, Univ. of Arizona, Tucson, 1968. 129 p. Diss. Abstr., 29(8): 3578, 1969.

Descriptors: Wastewater treatment, Tucson, Arizona, Aerobic conditions, Nitrification, Coliforms.

Studies were carried out on the removal of trace elements from sewage-works effluents by filtration through soil and grass, using different cycles of application. The best results were obtained with application for one day, followed by three dry days; this provided necessary aerobic environment for removal of trace metals, nitrification of reduced nitrogen compounds, and removal of coliform organisms, while the short flooding period provided the anaerobic conditions necessary for removal of nitrate by denitrification.

406 S SEWAGE SLUDGE DISPOSAL--BACK TO THE LAND?
Lewin, V. H.
Effluent Water Treat. J. (London), 8: 21-23, January 1968.

Descriptors: Human diseases, Odor, Forage crops, Public acceptance, England.

The author discusses the ways in which modern technical advances have made the disposal of liquid sludge on farm land an inexpensive and useful proposition and suggests that disposal of liquid sludge on agricultural land by tanker no longer be a health hazard or nuisance it once was. At Oxford, vacuum-dried sludge was acceptable to very few farmers and only for brief periods prior to ploughing but it was found that tanker distribution of digested activated sludge to grazing land was beneficial and could be practiced for 9 months of the year. By 1967 demand exceeded supply and more than 8 mil. gal. were disposed of in this way.

407 I SEMICHEMICAL HARDWOOD PULPING AND EFFLUENT TREATMENT
Malo, B. A.
J. Water Pollut. Contr. Fed., 39: 1875-1891, November 1967.

Descriptors: Reviews, Pulp and paper wastes, Soil types, Rates of application, United States.

Disposal of pulp and paper mill wastewater by irrigation is reviewed. Land requirements are 40 to 50 acres per mgd of wastewater. A BOD loading of 200 lb/acre/day is recommended as maximum. Soil treatment through 15 to 21 inches of sandy loam, silt loam or clay loam will remove 95% of the BOD. Color in Kraft mill wastewater will be reduced 99% by clay loam and 65% by sandy loam soils.

408 I THE MOVEMENT OF PESTICIDES IN SOILS
McCarty, P. L., and P. H. King
In: Proc. 21st Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1966.
p. 156-171.

Descriptors: Soil types, Microbial degradation, Soil contamination, Pesticides.

The results of the experiment on the movement of organic pesticides in soil were presented. Six organic phosphate pesticides, Thimet, Disyston, Methyl Parathion, Parathion, Trithion, and Ethion were tested in four types of soil of varying clay content. The conclusions were:

1. The extent of adsorption may be correlated with the clay content of the soil and described by Freundlich type isotherms, higher clay content has higher adsorption.

2. The rate of movement of pesticides in soils is inversely related to the extent of adsorption. The relative rates of movement may be determined from the pesticides properties such as molecular size and water solubility or the adsorption isotherm.

3. Leachability

   - Thimet, Disyston, Methyl Parathion and Parathion move rapidly in soil-water system.
   - Ethion and Trithion move more slowly.
   - Methyl Parathion breakdown was very rapid.
   - Thimet, Disyston and Trithion has intermediate stability, while Ethion was relatively persistent.
   - Parathion was fairly persistent initially but was degraded readily after biological acclimation took place.

4. Microbiological activity might reduce the effectiveness of the pesticides as well as the potential of harmful leachates from the soil.

409 M SOIL MANTLE AS A WASTEWATER TREATMENT SYSTEM
McGauhey, P. H., R. B. Krese, and J. H. Winneberger
University of California, Berkeley, SERL Report No. 66-7, 1966.
127 p.

Descriptors: Wastewater treatment, Soil microbiology, Reviews, California.

This project was to assemble pertinent literature from a variety of specialty fields and to reinterpret the data thus found in terms of the waste treatment ability of the earth's soil mantle. In the basis of this interpretation, the nature and scope of any further research needed before engineered soil systems can become a reality was defined. The technical and economic role of soil systems in the overall sequence of wastewater treatment necessary to protect the quality of groundwaters was evaluated. A series of progress reports expressing the findings of various phases of the study, and a final report on the subject of use of the biologically active soil mantle of the earth as an engineered system of waste treatment were prepared.

410 M SOIL MANTLE AS A WASTEWATER TREATMENT SYSTEM
McGauhey, P. H., and R. B. Krone
University of California, Berkeley, SERL Report No. 67-11. December 1967. 201 p.

Descriptors: Spreading basins, Nutrient removal, Subsurface irrigation, California, Clogging (soil).

This report includes a procedure for evaluating the percolative capacity of soil, comprehensive study of the permeability of the clogging mat or zone which controls the infiltrative capacity of a soil under wastewater loading, a study of the effect of the "hanging drop," which develops in some trench systems, study of the infiltration patterns, and comparative studies of surface and subsurface ponds as treatment systems. The report also contains comparative studies of surface spreading and spray application on the capacity of a surface area to accept wastewater, the feasibility of understanding natural soil beds to recover water for immediate use above ground, in the manner of the slow sand filter, the effects of various types of vegetation of spreading basins on the removal of primary nutrients and on the interaction of minor elements such as boron which may accumulate in the soil system and become toxic to vegetation, the uptake of materials which may cause a harvested plant to be toxic to men or animals or which may remove from a soil system significant amounts of chemicals which normally move freely with percolating water, and studies of the biological acceptance of a soil.

411 M WASTEWATER RECLAMATION AT WHITTIER NARROWS
McMichael, F. C., and J. E. McKee
Calif. State Water Quality Contr. Board, Sacramento, Publ. No. 33, 1966. 100 p.

Descriptors: Los Angeles, California, Spreading basins, Activated sludge effluents, Monitoring, Water quality data.

The general objective of this investigation was to determine the effects of intermittent percolation through soil of highly treated activated-sludge effluent on the quality of groundwater in the Whittier Narrows area. The project was designed to study the fate of significant mineral, organic, and biological constituents of renovated wastewater and the phenomena associated with their removal or transformation. The investigations were divided into three major categories. (1) A total of 25 wells in the vicinity of Whittier Narrows were monitored with respect to water quality at various elevations by means of a selective-depth pumping unit. (2) Test spreading basins were constructed and operated to study the phenomena associated with intermittent vertical percolation through the upper few feet of soil. (3) Laboratory soil columns were utilized to compare the degradation of the new linear alkylate sulfonates (LAS) with the conventional alkyl benzene sulfonates (ABS).

412 M THE SANTEE RECREATION PROJECT, SANTEE, CALIFORNIA--FINAL REPORT

Merrell, J. C., Jr., W. F. Jopling, R. F. Bott, A. Katko, and H. E. Pintler

U.S. Dept. Interior, Fed. Water Pollut. Contr. Admn., Research Service Publ. No. WP-20-7, 1967.

Descriptors: Santee, California, Viruses, Public acceptance, Planning, Recreational facilities.

This report presents the results of a study of the Santee Lakes, California. The Santee Lakes were deliberately planned to receive the community's reclaimed sewage effluent. The seven agency cooperative study evaluated the fate of virus, total and fecal streptococci as wastewater passed through conventional secondary treatment processes, sand filtration, and the recreational lakes. It was found that the additional treatment provided by intermittent sand filtration met most of the requirements for recreational use of the terminal ponds. No health hazards have been demonstrated by the viral or other findings and this fact had considerable impact in the promotion of public acceptance of the use of the recreational facilities.

413 S RECONSTRUCTION OF OFFERTON SEWAGE WORKS OF HAZEL GROVE AND BRAMHALL UDC

Morton, J., and F. Summerfield

Water Pollut. Contr. (London), 68: 85-92, 1969.

Descriptors: England, Costs, Sludge disposal.

The cost of sludge disposal at the Offerton Sewage Works in England which served about 20,000 people is discussed and compared to the use of drying beds.

414 M A DECADE OF STABILIZATION LAGOONS IN MICHIGAN WITH IRRIGATION AS ULTIMATE DISPOSAL OF EFFLUENT
Myers, E. A., and T. C. Williams
In: Proc. 2nd Int. Symp. Waste Treat. Lagoons, Kansas City, Mo., June 23-25, 1970. p. 89-92.

Descriptors: Michigan, Aerated lagoon effluents, Rates of application, Sprinkler irrigation, Surveys.

A general discussion of irrigation practice and lagoon treatment is given. Generally, application rates for irrigation range from 1/8 to 1/3 inches per hour with weekly amounts varying from 1 to 3 inches.

415 M MICROBIAL CONTENT OF AIR NEAR SEWAGE TREATMENT PLANTS
Napolitano, P. J., and D. R. Rowe
Water Sewage Works, 113: 480-483, December 1966.

Descriptors: Public health regulations, Aerosols, Coliforms.

The coliform discharge to the air from aeration tanks and trickling filters was measured under various weather conditions. At distances of 100 to 150 ft from the treatment units coliform counts ranged from approximately 30 percent of the count at the unit to nearly zero. The data collected indicated that approximately 50 percent of the coliform particles discharged were smaller than 5 microns and could be considered a health hazard. The coliform count at increased distances from a source is a function of the wind velocity and decreases with distance.

416 M BRITISH PRACTICE IN THE TERTIARY TREATMENT OF WASTEWATER
Oakley, H. R., and T. Cripps
J. Water Pollut. Contr. Fed., 41: 36-50, January 1969.

Descriptors: England, Legal aspects, Oxidation lagoons, Water quality standards, Tertiary treatment.

Studies effluent standards in Great Britain. Some legal aspects are discussed. Five methods of tertiary treatment given are: pebble bed clarifiers, land irrigation, microstraining, slow and rapid sand filtration, and effluent lagoons. In the section on land irrigation the author states that it is generally recognized that use of land for treatment of anything other than secondary tank effluent by irrigation is wasteful in a country where land is at a premium. Even irrigation with secondary effluent is suitable only for smaller works where this method can serve a particularly useful function in smoothing the inevitable variations in effluent quality. Properly managed land irrigation areas can produce effluents of consistently high quality. Land irrigation is not well suited to large works or to sites in urban areas or areas of high agricultural value.

417 S PIPELINES TO TRANSPORT ORGANIC WASTES
Olds, Jerome
Compost Sci., 7(3): 3-5, December 1967.

Descriptors: Wastewater treatment, Planning.

Developing pipeline systems to convey wastes to compost plants, sewage treatment plants, utilization sites.

418 I REUSE OF WASTEWATER IN GERMANY
Organ. Economic Cooperation and Development
Paris, France, 1969. 29 p.

Descriptors: Germany, Dairy wastes, Tannery wastes, Rates of application, Food processing wastes.

In 1955, 131 wastewater irrigation systems were in use in Germany, accounting for 3 percent of sewered sewage. Included are operations which dispose of wastes from brewing, starch factories, dairies, tanneries, sugar factories and textile mills. Wastewater applications seem low, the maximum recorded is 600 mm per year (about 24 inches).

419 M REMOVAL OF ABS AND OTHER SEWAGE COMPONENTS
BY INFILTRATION THROUGH SOILS
Page, H. G., and C. H. Wayman
Ground Water, 4: 10-17, January 1966.

Descriptors: Clogging (soil), Dissolved solids, Soil types, Colorado, Soil physical properties.

The nature and extent of movement of ABS and other sewage components through natural soils were studied in the laboratory and in the field north of Denver, Colorado. Small amounts of ABS and bacteria pass through soils and reach the zone of saturation, where they move laterally down-gradient several thousand feet.

In laboratory studies Denver sewage plant effluent was filtered through packed columns of eight types of soils. ABS was not significantly removed by most of the soils; however, muck greensand marl, and residual basalt soil initially removed up to 94 percent of the ABS. Bacterial clogging occurred quickly in the fine soils but only in modest amounts in the coarse sand, even after three months of flow. Field studies included analysis of river and irrigation water contaminated from sewage plant effluent, and well water from selected sites down-gradient between unlined irrigation ditches and the river. Concentrations of ABS and bacteria were significantly reduced during infiltration of irrigation ditch water to the water table. Dissolved solids showed practically no change between the ditches and the wells.

420 M WASTEWATER RENOVATION AND CONSERVATION
Parizek, R. R., et al.
Penn State Univ., Univ. Park, Penn., No. 23, 1967. 71 p.

Descriptors: Soil microbiology, Design data, Monitoring, Penn State, Pennsylvania, Soil physical properties.

The disposal of effluent on land in place of the customary disposal into natural waters would provide a means of purifying the water and making it available for reuse. The soil can be considered a living filter and utilization of those processes occurring naturally in pools, i.e., biological activities, the screening action of soil particles and the absorption of chemical nutrients by plant roots can serve as a final purifying treatment of the effluent. Described in detail are studies concerned with the geology and soils of the areas used as determined by extensive drilling operations, the exhaustive monitoring system that permitted a determination of the water quality of the effluent, the design of the irrigation system and analyses which provide information of the changes that were occurring in the effluent, soils and crops.

421 I DISPOSAL OF TANNERY WASTES
Parker, R. P.
In: Proc. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1967. p. 36-43.

Descriptors: Tannery wastes, Canada, Odor, Winter storage, Costs.

Beardmore & Co., Limited, located 50 miles west of Toronto, Ontario, processes 100,000 lb of cattle hide per day and their tannery wastewater flow rate is 0.72 mgd. During the spring, effluent which has been screened, settled and had pH adjustment, is sprayed at the rate of 2 in./day. This rate is excessive and because no runoff is tolerated, the summer rate is reduced to 0.3 in./day. Twitch grass is grown to a height of 5 in. and then mowed to a height of 2 in.

Spraying is from late April to late November or until ice forms on the turf. Lagoon capacity is 5 months of flow. Organic loading is 50 lb BOD per acre per day and the SAR is 30. This high SAR has not hampered the operation as the effluent is saturated with calcium carbonate and calcium hydroxide. Odor problems exist and masking agents are used in the spring. The installed cost of spray irrigation is $2,000 per acre. Maintenance expense is 10 cents per 1,000 gal. and the equivalent annual cost (amortizing over 5 years) is 20 cents per 1,000 gal.

422 M WASTEWATER REUSE--A SUPPLEMENTAL SUPPLY
Parkhurst, J. D.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 96(SA3): 653-663, June 1970.

Descriptors: Rates of application, Activated sludge effluents, Los Angeles, California, Anaerobic conditions, Groundwater recharge.

This article describes a wastewater reuse project undertaken in Los Angeles County. The Whittier Narrows Water Reclamation Plant with 10 mgd capacity has operated about 6-1/3 years (December 31, 1968) and supplied 95,811 acre-ft of good quality water with revenue of $1.48 million.

The Whittier Narrows plant uses the activated sludge process for pretreatment of wastewater and then percolates the effluent from the pretreatment into the ground. The reclaimed water is pumped from underground along with other natural groundwater for unrestricted use. The waste products which are removed by the treatment process are returned to the outfall sewer directly below the reclamation plant for subsequent treatment by anaerobic digestion at the downstream joint water pollution control plant. Prior to the development of the soft detergents, it was necessary to air strip to remove ABS in the wastewater, in order to comply with the water quality requirements. However, with the change in formulation by the manufacturers to biodegradable products, it has been possible to abandon the air stripping process completely.

423 M GOLF COURSE AND AIRPORT IRRIGATE WITH SEWAGE EFFLUENT

Parness, W. H.
Amer. City, 93: 90-92, May 1968.

Descriptors: Golf courses, California, Suspended solids, Operation and maintenance, Costs.

Discusses the financial aspects of irrigation with sewage effluent. The city of Livermore, California used this water to create four artificial lakes in the golf course; to irrigate the area near the runways which is leased for agriculture, adding to the airport's income; and to use for fire protection at the airport and golf course. The golf course became self-supporting in 1968. It operated on a budget of $155,600, but income was expected to be $163,000. The airport brought in a net profit that exceeded $7,000 in the first half of the fiscal year 1967-1968.

The high quality effluent from the sewage treatment plant is chlorinated and piped to the golf course lakes and irrigation systems. With its high nitrate content the effluent fosters turf and crop growth. About 35 percent of golf course maintenance centers around water, so this plant comprises a major asset.

In 1967 the city financed a $1.1 million plant expansion with the aid of a $360,000 grant plus their sewer connection fees. This converted the old trickling-filter process into an activated sludge system and doubled its capacity from 2.5 mgd to 5 mgd. The plant removes 96 percent of the BOD and 96 percent of the suspended solids. Financial aspects were also discussed.

424 I SPRAY IRRIGATION FROM THE MANUFACTURE OF HARDBOARD

Parsons, Ward
In: Proc. 22nd Ind. Waste Conf., Purdue Univ., Lafayette, Ind., 1967.
p. 602-607.

Descriptors: Costs, Sprinkler irrigation, Rates of application.

The use of spray irrigation systems has been successful in many instances, as in this case, but this method is not a cure-all and problems are to be expected, as in this case. Total costs are about $50.00 per million gallons, not including land or depreciation. The system is fairly simple to operate but requires about 100 acres/3 mgd. The author feels that operation of a spray irrigation system, while simple, has been oversimplified in literature, with the preconceived notion of success, and that this attitude should not prevail.

425 M *RENOVATION OF WASTEWATER EFFLUENT BY IRRIGATION OF FOREST LAND*

Pennypacker, Stanley, et al.

J. Water Pollut. Contr. Fed., 39: 285-296, February 1967.

Descriptors: Penn State, Pennsylvania, Phosphorus removal, Rates of application, Denitrification, Wastewater treatment.

Penn State University at University Park, Pennsylvania, successfully demonstrated the use of forested land for wastewater disposal and renovation at rates of up to 4 inches per week, or 1 mgd with 129 acres. The study area consisted of mixed hardwood, red pine and an old field. BOD removal by the treatment plant was about 85-92 percent and hence the ability of the soil to remove BOD was not checked. However, the phosphorus removal was up to 99.5 percent (down to 0.04 mg/l) and nitrate removal as high as 86 percent.

426 M *SALT BUILD-UP FROM SEWAGE EFFLUENT IRRIGATION*

Peterson, H. B.

In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 31-44.

Descriptors: Salinity, Vegetation damage, Louisiana, Dissolved solids.

Four types of soluble salts in natural waters and in sewage effluents were studied to determine the salinity status of effluent waters from disposal systems and assess the potential salt build-up resulting from the use of these waters.

1. *Common Salt. In arid regions, the suggested limit for salinity in irrigation water is less than 500 mg/l of total dissolved solids without any detrimental effect on crops. Wastewater with a TDS range from 500 to 5,000 mg/l may be used depending upon types of crops. In the humid region the above criteria can serve only as a rough guide and the accepted amount of normal salt could likely be increased.*

2. *Exchangeable sodium. Relatively low-concentration of sodium and chloride salts applied on foliage can cause harmful salt build-up on sensitive crops.*

427 M VIABILITY OF LONG STORAGED AIRBORNE BACTERIAL AEROSOLS

Poon, C. P. C.
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 94(SA6): 1137-1146,
December 1968.

Descriptors: Pathogenic bacteria, Salinity, Aerosols, Coliforms, Rhode Island.

Many of the aerosols from sewage treatment plants carry respiratory pathogenic bacteria. Those with nuclei from 6-10 microns can be retained in the upper respiratory tract and 3-6 micron particles can lodge in the bronchioles. Smaller particles from 3 microns to single cells can even penetrate to the alveoli.

Factors governing the viability of airborne bacteria include temperature, relative humidity, particle size, presence of toxic material, salts and growth medium.

Radioactive tagged Escherichia coli cells were aerosolized from distilled water suspension and stored for 4 hr in a storage chamber where temperature and relative humidity were under control. It was found that increase of air temperature and/or decrease of relative humidity increased the death rate. The death rate was proportional to the rate of water evaporation.

428 M BACTERIOLOGICAL AND VIROLOGICAL INVESTIGATIONS ON THE UTILIZATION OF SEWAGE IN AGRICULTURE IN AREAS OF LOWER SAXONY

Popp, L.
Schriftenreihe Kuratoriums Kulturbauwesen (Hamburg), No. 16,
p. 43-80, 1967.

Descriptors: Pathogenic bacteria, Germany, Subsurface irrigation, Human diseases, Viruses.

Detailed laboratory and field experiments have been carried out to assess the effects of agricultural utilization of sewage in areas of Lower Saxony. Different processes of irrigation, application as artificial rain on plants and soil, and the effect of treatment by subsoil irrigation and of drainage water from sludge storage tanks on receiving waters were investigated in connection with hygienic aspects and with special reference to the viability of pathogenic bacteria.

429 M MICROBIAL PROBLEMS IN GROUNDWATER
Robeck, G. G.
Ground Water, 7(3): 33-35, May-June 1969.

Descriptors: Coliforms, Costs, Viruses, Denitrification.

Research work has indicated that non-fecal coliform can develop or increase at a considerable depth within a sewage recharge system. This seems to point to the need of a more specific indicator of fecal organisms, and the need for the removal of waste that might be food and nutrients for the organisms, before wastewater percolates down more than one or two feet.

Using fecal coliform as a test for the safety of well water may well be more meaningful than the old test, as well as being easier to run. The cost and hazards of making studies concerning enteric viruses limit work to small scale tests where cracks, weathering, sunlight, etc. can only be simulated. Using groundwater rates of a few feet per day, no significant difference in the movement of a 30-micro-milicron virus and a 1-micron coliform was detected, and under the right conditions the coliform multiplied and penetrated deeper than the smaller virus.

The amount of virus removed by 2 ft of sand varies with the flow rate, but in almost every case the virus was removed amazingly well. It was also found that organisms native to domestic sewage can act as a seed for developing a population in the soil to degrade detergents and other organic materials.

Oxidizing ammonia to nitrates is for some a cause of concern. There are several possibilities to solve the denitrification problem: (1) organisms can be developed in a waste treatment column of activated carbon or sand that will create denitrification; (2) the nitrates could be removed when the water is withdrawn from the ground by clinoptilolite, a natural zeolite that will selectively remove ammonia-nitrogen from wastewater. The problems still need further investigations and tests before they will be practical to put into use.

430 M HYGIENIC REQUIREMENTS FOR IRRIGATION WITH SEWAGE OUTSIDE THE USSR
Romanenko, N. A.
Hyg. Sanit. (USSR), 34(10-12): 275-278, October 1969.

Descriptors: Public health regulations, Reviews, Wastewater treatment.

Reviews the practices, policies, regulations, and health standards that have evolved out of the practice of using soil systems for disposal and purification of sewage, sludge, and effluent.

431 M ADVANCED WASTE TREATMENT IN NASSAU COUNTY, N.Y.
Rose, J. L.
Water Wastes Eng., 7: 38-39, February 1970.

Descriptors: New York, Groundwater recharge, Costs, Tertiary treatment, Injection wells.

This is a report on a 400 gpm demonstration plant for tertiary treatment at East Rockaway, New York. Engineering evaluations of the cost of tertiary treatment prior to injection are given. The plant flowsheet includes coagulation, filtration, carbon adsorption, and degasification. Effluent is pumped 1/2 mile to a test injection site where recharging at depths of 420 to 480 feet will take place. If successful, more injection wells will be created to repel salt water intrusion in western Nassau County.

432 M ULTIMATE DISPOSAL OF WASTES TO SOIL
Routson, R. C., and R. E. Wildung
Eng. Progress Symp. Series, 65(97): 19-25, 1969.

Descriptors: Soil chemical properties, Soil microbiology, Wastewater disposal.

Soil is a dynamic system which is capable of reacting with a broad spectrum of extraneous components. The nature of these reactions is such that soil may function as a medium for either waste storage or for ultimate waste disposal. This paper will elaborate upon those aspects of the soil system which are relevant to the problems of ultimate waste disposal. Since soil represents a relatively thin surface layer and is generally an integral part of man's environment, soil disposal alone should not be considered permanent. Furthermore, concentration mechanisms in the soil often negate the usefulness of soil as a medium for disposal by dispersion or dilution. However, both transformational and recyclization and reuse mechanisms occur as normal functions of most soil systems. Thus, the latter two ultimate disposal methods will be emphasized in the following discussion of nature of the soil, soil properties amenable to waste disposal, and general soil waste interactions.

433 M WHAT HAPPENS IN SOIL-DISPOSAL OF WASTES
Routson, R. C., and R. E. Wildung
Ind. Water Eng., 7: 25-27, October 1970.

Descriptors: Soil chemical properties, Soil contamination, Soil physical properties, Soil microbiology, Reviews.

The soil is a combination of chemical, physical and biological aspects which work upon substances to change them into organic or inorganic forms. This article discusses some of these actions upon carbon, sulfur, phosphorus, and nitrogen compounds, explaining some of the limiting conditions for the soil to process these materials.

434 S DIE ABWASSERSCHLAMMVERWERTUNG AUF LANDWIRTSCAFTLICHEN NUTZFLACHEN (THE UTILIZATION OF SEWAGE SLUDGE ON AGRICULTURAL LAND)
Schaffer, G.
Z. Acker-Pflanzenbau (Berlin), 126: 73-99, January 1967.

Descriptors: Aerobic digestion, Recycling nutrients, Sludge disposal, Europe.

This paper is based on the experimental work of 19 authors on the value of sewage sludge to agriculture and contains details of the problems and difficulties which are experienced owing to the different properties present in sewage sludge which effect sludge decomposition both in the digestion tank and in the soil during composting. The value of sludge as a commercial product in view of its low nutrient content and future aspects regarding crop rotation are discussed.

435 M DISPOSAL (CONSERVATION) OF WATER BY PERCOLATION IN SOIL
Schliff, L. I.
In: Agricultural Waste Waters, Doneen, L. D. (ed.), Univ. of Calif., Water Resources Center Report No. 10, April 1966. p. 203-215.

Descriptors: Soil physical properties, California, Soil types, Deep percolation, Reviews.

The major factors affecting percolation rates are permeability and gradient. Permeability is affected by soil texture and soil structure. Soils have two types of pores, capillary (small as in clays) and gravity (relatively large as in sand). The volume of water held in small pores is called field capacity and the volume of water held in all pores is called field saturation.

436 M BIOLOGICAL RECOVERY OF WASTEWATER

Schulze, K. L.
J. Water Pollut. Contr. Fed., 38: 1944-1958, December 1966.

Descriptors: Groundwater recharge, Odor, Winter storage, Primary effluent, Tertiary treatment.

The need for better quality in renovated wastewater has prompted the development of tertiary or advanced treatment methods. After biological tertiary treatment it is considered a good approach to use the effluent for irrigational purposes. The many tons of nitrogen and phosphorous contained in the effluents would be a valuable asset in the production of crops and timber as well as serving to replenish the groundwater table. It is preferable to use tertiary effluents instead of primary or secondary to cut down on problems of putrescible matter and odors. Even with tertiary treated effluents there may be problems such as accumulation of sodium and chloride in the soil. There would also be the difficulty and expense of storage of the effluent during the winter months. However, in considering the problems and inadequacies of today's treatments, it is imperative to reorient our thinking and to develop new approaches to the problem.

437 M SOIL SYSTEMS FOR LIQUID WASTE TREATMENT AND DISPOSAL: ENVIRONMENTAL FACTORS

Schwartz, W. A., and T. W. Bendixen
J. Water Pollut. Contr. Fed., 42: 624-630, April 1970.

Descriptors: Climatic data, Ohio, Denitrification, Soil types, Phosphorus removal.

Studies were performed at the Robert A. Taft Water Research Center in Cincinnati and at Loveland, Ohio, on the effects of several environmental factors on soil treatment efficiency. The effects of depth to groundwater, climate, and vegetation on the removal of COD, N, P, and MBAS and the maintenance of hydraulic acceptance were studied. A minimum depth to groundwater of 2 ft for satisfactory COD removal and 4 ft for satisfactory nitrification was found. In general 5 ft represents an adequate depth and 1 ft is completely inadequate. Biological activity is the main victim of cold weather, however, this can be partially overcome by achieving biological maturity in the system prior to the onset of cold weather.

Cultivation of vegetation served to extend hydraulic longevity by a factor of about 2. Trickling filter effluent was dosed to 6 inch buried soil lysimeters at a rate of 1.6 in./day. Removals of total nitrogen and total phosphorus were 85 and 99 percent, respectively.

438 M THE AGRICULTURAL USE OF THE BLACK WATERS
Secretary of the Hydraulic Resources, Hydrological Commission of the Cuenca of the Valley of Mexico, 1970.

Descriptors: Mexico, Water reuse, Legal aspects, Reviews, Planning.

The system of drainage of the Valley of Mexico and the agricultural use of its waters is described. The black waters (wastewaters) are considered as a hydraulic source. Studies and investigations done about the black waters of the river basin of the Valley and region of the Mezquital, Hgo., are reviewed, as well as some studies about the development of the agricultural use of the black waters. Legal aspects are not considered.

439 M NITROGEN CYCLE IN GROUND WATER
Sepp, E.
Bur. Sanit. Eng., Calif. State Dept. Pub. Health, 1970.

Descriptors: Ion exchange, California, Nitrate contamination, Soil microbiology, Groundwater contamination.

The sources of nitrogen compounds in soil and ground water are numerous and diverse. The compounds undergo complex transformations caused by environmental factors. Atmospheric precipitation adds from 0.7 to 14 pounds of nitrogen per acre to the soil annually. Nitrogen fixing organisms in the soil may add from a few pounds to 200 pounds per acre of nitrogen per year. Depending on circumstance, either agricultural practice or land disposal of sewage may be the major contributor of nitrogen to groundwater. Ammonia and ammonium ion are held close to soil surface by adsorption and cation-exchange reactions. Nitrate and nitrite ions, however, move freely with the percolating water. Experiments showed how nitrogen may be removed from the soil by cropping, leaching, erosion, or volatilization. At present, not enough is known to establish design criteria for controlling nitrate reduction in the aquifer.

440 M HEALTH FACTORS IN THE REUSE OF WASTE WATER FOR AGRICULTURAL, INDUSTRIAL, AND MUNICIPAL PURPOSES
Shuval, H. D.
In: Problems in Community Wastes Management, Geneva, World Health Organization, 1969. p. 76-89.

Descriptors: Coliforms, Viruses, Groundwater recharge, Bibliographies.

Recognizing that water shortages are resulting in an increased usage of wastewater, public health considerations are becoming more and more important. Coliform organism reductions are well documented--one report gives a reduction of 99.99 percent with a 28-day detention--but viruses still remain as a problem, although chlorination is quite useful. However, it has been found that with proper regulation, the use of effluents for crop irrigation will not present any problems. The use of wastewater for industrial and municipal use, as well as for groundwater recharge is discussed, and the study concludes that, within reason, wastewater reuse is feasible and practical. A bibliography of 35 items is included.

441 M RENOVATION OF MUNICIPAL SEWAGE EFFLUENT FOR GROUND-WATER RECHARGE THROUGH FOREST IRRIGATION
Sopper, W. E.
In: Proc. Int. Conf. Water Peace, Pap. No. 571, Washington, D.C., May 23-31, 1967.

Descriptors: Penn State, Pennsylvania, Rates of application, Tertiary treatment, Wastewater treatment, Groundwater recharge.

Centre County, Pennsylvania had a problem of water supply shortage and pollution of existing supply from the dumping of treated sewage into the stream. A study project was set up to attempt to solve these problems. Effluent treated by primary settling, standard and high-rate trickling filters, modified activated sludge process, final settling, and chlorination was used to irrigate stands of white spruce, red pine, and a 60-year-old natural mixed oak stand. The effluent was applied at a rate of 0.25 in./hr, at 1 to 2 in./wk, except one plot which received 4 in./wk. The effluent was renovated effectively and the groundwater level was increased.

442 M WASTE WATER RENOVATION FOR REUSE: KEY TO OPTIMUM USE OF WATER RESOURCES
Sopper, W. E.
Water Research (London), 2: 471-480, September 1968.

Descriptors: Rates of application, Wastewater treatment, Penn State, Pennsylvania, Groundwater recharge.

In order to meet the increasing demand for sewage purification, treated municipal waste water was applied to forested areas at various rates of application to determine the feasibility of land disposal of such effluents *and to determine to what extent effluents could be renovated by the biosystem and recharged to the groundwater reservoir. It was found that satisfactory renovation of waste water was achieved when the effluent was applied at rates of 1, 2, and 4 in. per week in forested areas during the period April-November. Approximately 90 percent of the water, applied at 2 in. per week during this period was recharged to the groundwater reservoir. Results of this study appear to indicate that municipal wastewater can be satisfactorily renovated for groundwater recharge through irrigation of forested areas under controlled conditions.*

443 S REVEGETATION OF STRIP MINE SPOIL BANKS THROUGH IRRIGATION WITH MUNICIPAL SEWAGE EFFLUENT AND SLUDGE

Sopper, William E., John A. Dickerson, Clifford F. Hunt, and Louis T. Kardos
Univ. Park, Penn., Penn State Univ., Institute for Research on Land & Water Resources, Reprint Series No. 20, 1970. 6 p.

Descriptors: Penn State, Pennsylvania, Plant diseases, Forage crops, Soil chemical properties, Land reclamation.

Two years' research at Penn State indicates that municipal waste waters may be used to reclaim and revegetate many of the barren, strip-mined spoil banks that exist throughout the Appalachian area. Tree seedling survival and growth in spoil material treated with sewage effluent and sludge was excellent. The controls in untreated material had 100% mortality. Treatments were very effective in establishing a ground cover of grasses and legumes, particularly in those that included sludge applications. Percolate samples collected also indicated that considerable amounts of dissolved minerals were removed by the spoil material and the spoil material and the quality of the percolating water was greatly improved.

Biological treatment and hydraulic longevity and effects made on them by the different seasons and by vegetation are discussed. Plant assimilation of nitrogen and phosphate were also discussed.

444 M NEW APPROACHES TO WASTEWATER TREATMENT

Stenburg, R. L., J. J. Convery, and C. L. Swanson
Amer. Soc. Civil Eng., J. Sanit. Eng. Div., 94(SA6): 1121-1136, December 1968.

Descriptors: Tertiary treatment, Design data, Costs, Wastewater treatment, Ohio.

Pilot plant and full-scale plant research and development studies of conventional process modifications and tertiary processes will serve to develop design data and provide more accurate and reliable cost-quality relationships for many individual and combined treatment processes. Basic research and laboratory-scale studies of other approaches to wastewater treatment are also being conducted. As new processes are developed, they will be evaluated in pilot plant and full-scale facilities.

Waste characteristics vary widely with locations and each waste stream must be considered individually in selecting unit processes.

Costs of tertiary treatment will be high by present standards.

Greatly increased expenditures will be required to eliminate pollution of our lakes and streams. Water reuse by industry and for nonpotable purposes will be necessary to reduce the financial burden. Potable water reuse by mixing with fresh water supplies is considered to be a distinct possibility in the future.

445 I AUTOMATIC WATER AND WASTE TREATMENT PLANTS IN OPERATION

Stone, R., and E. T. Conrad
Civil Eng., Amer. Soc. Civil Eng., 40: 37-40, May 1970. Selected Water Resource Abstracts, 3(24): 34.

Descriptors: Wastewater treatment, Recreational facilities, Sprinkler irrigation, California, Design data.

Description of an automatic waste treatment plant which reuses purified wastewater for recreational purposes, with a portion of the effluent being used for hillside irrigation. The effluent for irrigation is not recharged into the recreational system.

446 M WASTEWATER FOR GOLF COURSE IRRIGATION

Sullivan, D.
Water Sewage Works, 117: 153-159, May 1970.

Descriptors: Sprinkler irrigation, California, Golf courses, Dissolved solids, Water quality data.

Treated effluent is used to spray irrigate a golf course in Ventura, California. A 4-acre test plot was preconditioned with 5 million gallons *of digested sludge. Three test wells were constructed and old orchard, seaside bent, and Kentucky blue grass were used. The effluent TDS was 1,702 mg/l. chlorides 380 mg/l, and total nitrogen 18.4 mg/l. TDS in the test wells ranged from 1,192 to 8,128 mg/l.*

447 M DEGRADATION OF WASTEWATER ORGANICS IN SOIL
Thomas, R. E., and T. W. Bendixen
J. Water Pollut. Contr. Fed., 41: 808-813, May 1969.

Descriptors: Soil microbiology, Primary effluent, Septic tanks, Rates of application.

The results of lysimeter studies show that soil microorganisms can digest much of the organic carbon contained in primary and secondary wastewater effluents. About 80 percent of the organic carbon from septic tank effluent was digested under a variety of conditions. Large variations in temperature, the loading rate, and the duration of dosing had no effect on the percentage of the organic carbon which was degraded. Organic carbon was applied at rates up to 31 tons/yr/acre. A loading rate of 3.7 tons/yr/acre resulted in a net reduction in the organic carbon content of a silt-loam soil. CO_2, equivalent to about 60 percent of the degraded organic carbon, was released at the soil surface in one experiment. Sludge loadings equivalent to 30 tons/yr/acre of organic carbon can be applied to sandy soils for extended periods without resulting in a detrimental accumulation of organic residues in the soil. Based on typical values for the composition of sludge, this would be equal to 100 tons/yr/acre of dried digested sludge solids. Proper management of liquid and organic carbon loads can result in long-term continuous operation, with only minor changes in the organic carbon content of the soil. Future studies are planned to evaluate the interaction between loading factors and the alteration of the physical and chemical properties of the soil.

448 M SOIL RESPONSE TO SEWAGE EFFLUENT IRRIGATION
Thomas, R. E., and J. P. Law, Jr.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 5-12.

Descriptors: Reviews, Furrow irrigation, Overland flow, Wastewater treatment, Soil chemical properties.

A review of soil systems that have been used for the treatment of wastewater. The soil systems investigated by the authors were grouped into

4 systems that included (1) infiltration basins, (2) ridge and furrow, (3) spray irrigation, and (4) spray-runoff. These systems were being used specially for wastewater treatment rather than irrigation of economic crops. Each system has its design features that provide advantages for particular operating conditions and needs. Many industrial and most domestic wastewaters are suitable for irrigation use under good management practices.

449 M SOIL CHEMICAL CHANGES AND INFILTRATION RATE REDUCTION UNDER SEWAGE SPREADING
Thomas, R. E., W. A. Schwartz, and T. W. Bendixen
Soil Sci. Soc. Amer., Proc. 30(5): 641-646, September-October 1966.

Descriptors: Aerobic conditions, Anaerobic conditions, Soil chemical properties, Clogging (soil).

Laboratory and field lysimeters were used to investigate the location and nature of soil-pore clogging under sewage spreading. The site of clogging was located by determining, with a seepage meter, the impedance profile at 0.5 cm depth interval. Soil samples were analyzed for sulfide, iron, phosphate total organic matter, polysaccharide, and polyuroride to evaluate possible causative relationships. The infiltration rate loss exhibited three phases: phase I, a slow reduction under aerobic conditions; phase II, a rapid reduction under aerobic conditions; and phase III, a further gradual decline under anaerobic conditions. The primary site of clogging was in the 0 to 1 cm depth of soil. Although sulfide was an indicator of anaerobic conditions, it was not a primary cause of clogging. Accumulations of the other five measured constituents may contribute to clogging in both phase I and phase II. Organic matter was the only probable clogging agent to decline as the infiltration rate was partially recovered in a rest cycle.

450 I AN EVALUATION OF CANNERY WASTE DISPOSAL BY OVERLAND FLOW SPRAY IRRIGATION
Thornwaite, C. W., Associates
Publications in Climatology, Elmer, New Jersey, 22(2), September 1969.
73 p.

Descriptors: Food processing wastes, Overland flow, Phosphorus removal, Paris, Texas, Costs.

In 1968, a research project was initiated by the Campbell Soup Company Plant in Paris, Texas, to study in depth its system of spray irrigation with overland flow. The system, which has been operating since 1964, has been outstandingly successful. There are "BOD removals of 99 percent to a level of 3-6 mgd/l, and nitrogen and phosphorus removals of up to 90 percent, at a cost of about five cents/1,000 gallons." The project ran for one year, during which 15 acres of the total 500-acre site were studied extensively regarding climatological, agricultural, biological, hydrological and chemical factors.

In conventional spray irrigation systems, water percolates into the soil and flows away via an underground route. In the Paris system the water is sprayed at the top of a slope, then percolates through the dense sod to the soil surface, and trickles downslope in a thin sheet. It is collected in a terrace at the foot of the slope and flows into a receiving stream via prepared waterways. Thus, effluent could be collected at any stage during the purification process without fear of mixed samples.

Of the many conclusions arrived at by the study, one of the most interesting is that although there is a decrease of biological activity in winter, an increase in microbial population in cold weather compensates for the reduced metabolic activity, and no reduction in efficiency occurs. Previously, it had been believed that impurities were being adsorbed upon the surface of the vegetation and held there until the weather warmed again. It also appears that microorganisms may go through an evolutionary phase, which adapts them specifically to the effluent. This may be the reason for the greater efficiency of older portions of the system.

451 S EXPERIENCES WITH THE DISPOSAL OF SEWAGE SLUDGE IN AGRICULTURE

Triebel, W.

Korresp. Abwass. (Germany), 10: 11-16, 1966.

Descriptors: Public health regulations, Soil microbiology, Germany, Vegetable crops, Evapotranspiration.

In a detailed report on the activities of the Niersverband, which is responsible for the protection of German waters in the 1348-km^2 catchment area between the Rhine and the Maas, special reference is made to the disposal and utilization of sewage sludge in agriculture. Details are also given of the sewage-treatment facilities at the group sewage works of the Niersverband. The increased use of sewage sludge in agriculture is illustrated in tables, which show that since 1960 the group sewage works have supplied on average 820 farms, resulting in increased yields of truck crops, especially beet, and pastures. Studies showed also that wet sludge, deposited on grassland, had lasting effects in reducing and thus regulating the soil evaporation. Special reference is made to the advantageous sorption capacity of digested sludge which *greatly improves dry soil, contrary to dried sludge which, owing to irreversible hydrophobia (caused by the drying process) has adverse effects on the sorptive soil structure. Compared with artificial fertilizers the use of sludge in agriculture presents more work; this, however, is compensated by the valuable properties in the humus, restoring the exploited soil. Existing parasites and micro-organisms are destroyed by pasteurization plants which have recently been installed, operating at a temperature of 65° C and for a period of 15 min, to comply with health regulations.*

452 I THE COST OF CLEAN WATER, VOL. III, INDUSTRIAL WASTE PROFILES NO. 6--CANNED AND FROZEN FRUITS AND VEGETABLES

U.S. Dept. Interior, Washington, D.C., Fed. Water Pollut. Contr. Admn. Publ. No. IWP-6, September 1967. 105 p.

Descriptors: Costs, Oxidation lagoons, Food processing wastes, Rates of application.

This report deals mainly with waste quantities, waste treatment processes and costs. An estimated 38 percent of the industry's wastes are not discharged to municipal sewers and of these only 1/3 provide waste treatment more extensive than screening. Oxidation ponds and spray irrigation are the predominant secondary treatment methods.

Spray irrigation loading rates are included for various fruit and vegetable processing wastes. Average application rates vary from 0.3 to 3.6 inches per day with BOD loadings of 20-860 lb/day/acre.

453 I WATER QUALITY RESEARCH FOR USE OF INDUSTRIAL WASTEWATER IN LAND TREATMENT

Vermes, L.

Proc. German Academy Agr. Sci. (Berlin), No. 106, 1970. 11 p.

Descriptors: Water quality standards, Hungary, Soil chemical properties, Ion exchange, Salinity.

The most fundamental requirement of the possibility of using wastewater in agriculture relates to water quality. A study of the quality of the wastewater in various industries was undertaken. In Hungary, the quality requirements for irrigation water are set by the composition of the soil. Since most of the soils tend toward alkalinization--Na ions can replace exchangeable cations in the soil complex. This exchange process must be prevented, and the dissolved salt level of the irrigation water and the Na content, expressed as a percentage of cations, must be stringently circumscribed.

The quality of wastewater containing a high concentration of salt cannot be chemically influenced, but the concentration can be reduced by dilution. A dilution ratio not harmful to plants or soil was therefore established.

454 S PLANT EXPERIMENTS WITH SEWAGE SLUDGE FROM HELSINGFORS
Viitasalo, Ilkka
Grundfoerbattring (Uppsala, Swed.), 22(1-2): 22-23, January 1969.

Descriptors: Rates of application, Grain crops, Spreading basins.

Root crops and oats were cultured in soil enriched with sewage sludge. The sludge was treated in dry beds, by vacuum filtration or by precipitation with $FeSO_4$. Dosage for dry bed sludge were given as 80 tons/acre, content of dry matter was not mentioned. Maximum crops were harvested when additions of N and K were given.

455 M WASTES IN RELATION TO AGRICULTURE AND FORESTRY
Wadleigh, Cecil H.
U.S. Dept. Agr., Washington, D.C., Misc. Publ. No. 1065, March 1968. 112 p.

Descriptors: Soil contamination, Aerosols, Human diseases, Silviculture.

This report provides terse consideration to 10 major categories of entities that contaminate the air, water, and soil of our environment in relation to agricultural and forestry endeavor. A brief discussion is also presented on economic evaluation. A few comments are offered on each category about the importance of the problems, the extent to which agriculture and forestry are involved, contributions that have been made to ameliorate the problems by research in agriculture and forestry, and an indication of the need for new or better information and technology towards meeting pressing problems. More complete discussion is presented in the four appendices.

456 M WATER RECLAMATION AND REUSE
Weber, W. J., Jr.
J. Water Pollut. Contr. Fed., 39: 734-741, May 1967.

Descriptors: Reviews, Costs, Water reuse, Design data.

Literature review of a symposium on Water Conservation by Reuse, by the American Institute of Chemical Engineers at its 59th Annual Meeting. Gives location and purpose of a large variety of systems and states general information on the types of system efficiency, cost, and health aspects.

457 M GROUNDWATER RECHARGE WITH TREATED MUNICIPAL EFFLUENT

Wells, D. M.
In: Proc. Symp. Munic. Sewage Effluent for Irrigation, Wilson, C. W., and F. E. Beckett (ed.), Ruston, Louisiana, Louisiana Polytechnic Inst., July 30, 1968. p. 61-73.

Descriptors: Lubbock, Texas, Groundwater contamination, Groundwater recharge.

The author indicated five paths through which municipal effluent recharge can take place. They are accidental recharge, recharge through irrigation, recharge from streams, recharge from cesspools or septic tanks, and deliberate recharge. Practically all of the recharge in the past has resulted from the natural hydrologic cycle, and it does not appear that this pattern will be appreciably changed in the future. It does appear, however, that the deliberate use of treated effluent for groundwater recharge will increase in the future, particularly in arid and semi-arid areas of the country that are rapidly depleting their groundwater resources. Data on the groundwater quality below the irrigation system at Lubbock, Texas, are given.

458 M INJECTION OF RECLAIMED WASTEWATER INTO CONFINED AQUIFERS

Wesner, G. M., and D. C. Baier
J. Amer. Water Works Ass., 62: 203-210, March 1970.

Descriptors: Groundwater recharge, Pathogenic bacteria, Water quality data, Trickling filter effluent, Injection wells.

Three multi-casing injection wells and 13 multi-casing observation wells were constructed to determine feasibility of injecting treated wastewater into the confined aquifer. The injected effluent was trickling filter effluent that was treated in a 300 gpm capacity plant which consists of clarification with alum as the coagulant, filtration through anthracite and sand media, and chlorination. The result of the second phase shows that the multiple-casing injection wells have performed very satisfactorily and have several operational advantages over a single casing well in a multiple aquifer system. The treated trickling filter effluent is injectable and would not cause excessive well clogging.

Coliform bacteria have appeared sporadically 100 ft from the injection well; have not appeared at 245 ft, but have appeared at 545 ft away. The coliforms observed at 545 ft are not believed to have been transported in the injection water. Human intestinal viruses have never been found in the injection water or in any of the observation wells.

Many chemical constituents do not move conservatively in the injected water. Hardness and other oxygen-demanding materials are significantly reduced by travel in the confined aquifer.

Some highly resistant soluble organic material causes odor and taste, and this material is not sufficiently removed or altered by movement through 545 ft of the confined aquifer.

459 M FEASIBILITY OF REUSE OF TREATED WASTEWATER FOR IRRIGATION, FERTILIZATION AND GROUNDWATER RECHARGE IN IDAHO

Williams, R. E., D. D. Eier, and A. T. Wallace
Idaho Bur. Mines Geol. Pam. 143, Moscow, Idaho, October 1969. 110 p.

Descriptors: Water quality standards, Dissolved solids, Tertiary treatment, Idaho, Groundwater recharge.

It has been demonstrated that under appropriate hydrogeologic conditions wastewater renovated by a porous medium can be expected to meet U.S. Public Health Service drinking water standards. Appropriate hydrogeologic conditions include the presence of an unconsolidated porous medium (such as sand) through which the wastewater can move an appreciable distance (which will vary with geologic conditions) before entering a water supply; the absence of surficial, jointed rocks through which the wastewater might move without appreciable adsorption of dissolved solids by the porous medium; and a water table depth of at least five feet. Hydrogeologic conditions less than optimal will result in less than optimal renovation of the wastewater, in which case care must be taken during application if water supply sources are located near the disposal area. Only rarely will a given hydrogeologic environment not renovate wastewater to the equivalent of secondary (biological) treatment. In many cases renovation of wastewater by vegetation and the geologic column can be substituted for tertiary treatment. Terrestrial disposal has also been used in lieu of secondary treatment.

460 M RECLAIMING SEWAGE EFFLUENT

Wilson, L. G., and G. S. Lehman
Prog. Agr. Ariz. College Agr., Univ. of Arizona, Tucson, 19: 22-24, April 1967.

especially suitable for deep, moderately permeable soils. The sprinkler method is especially applicable to rapidly permeable and shallow soils and where light applications are in order.

Sewage irrigation is discussed briefly. An increase in salinity levels of domestic sewage of about 15 to 30 percent above that of the tap water is to be expected. Industries using boron, or communities where boron-based detergents are greatly used, may produce an unreclaimable effluent. Irrigation with treated sewage effluent should preferably be done by surface methods. A sample irrigation project, including a cost analysis, is given.

SECTION VII

ABSTRACTS 1971 AND LATER

464 M IRRIGATE WITH THE WASTEWATER
Anonymous
Amer. City, 87: 24, March 1972.

Descriptors: Golf courses, Sprinkler irrigation, Florida, Planning, Soil physical properties.

Plans for St. Petersburg, Florida, are to irrigate golf courses, city parks, and public rights-of-way with treated effluent. The effluent from four treatment plants is presently discharged into Tampa Bay and Boca Ciega Bay at a rate of 30 mgd. The lawns surrounding two of the treatment plants have been converted to effluent irrigation. A 10-acre test site will be used to study health effects, safety, and soil permeability. The lawns at the Albert Whitted Wastewater Plant are irrigated using dial-type sprinkler heads with push-button mechanical-clock controls. The soil is sandy and the demand for lawn irrigation water is heavy. Water demand dropped from 40 mgd to 24 mgd on the day following a heavy rainfall.

465 S CHICAGO RECLAIMING STRIP MINES WITH SEWAGE SLUDGE
Anonymous
Civil Eng., 42: 98-102, September 1972.

Descriptors: Chicago, Illinois, Costs, Sludge disposal, Land reclamation, Spray disposal.

This article covers incineration, dewatering, drying. These were other alternatives studied by Chicago engineers. Then several years ago, MSD decided--following an intensive research program--the most attractive alternative to improving existing sludge-disposal operations was land reclamation. The plan was to digest sludge and transport it to rural land beyond city limits. Spraying digested sludge on abandoned strip-mined land, or on other areas with poor soils (e.g., lowgrade pastures) would *have several unique advantages: it would eliminate land, air, and water pollution stemming from sludge processing in the urban area; cost less than other sludge disposal methods; solve the problem of hunting for lagoon space in urban areas; and it would make beneficial use of the organic materials, nutrients, and water making up sludge.*

466 S USING ORGANIC WASTES TO BENEFIT FARMS AND RURAL AREAS
Anonymous
Compost Sci., 14(1): 7-9, January-February 1973.

Descriptors: Pennsylvania, Sludge disposal, Recycling nutrients, Wastewater disposal, Legal aspects.

For years, waste disposal methods in cities and farms have simply tried to get rid of those wastes as cheaply and quickly as possible. In many areas, dumps burn almost continually; water supplies are fouled; state regulations make many old installations illegal. In the future, there will be a much closer look at recycling wastes--specifically how to use wastes so they benefit the land, the people in rural areas, so they aid crop growth, and even produce methane gas for heating, lighting and powering trucks and tractors. Some of the research and projects now under way which give some information on how organic wastes can be used--or are already being used--to benefit Pennsylvania farms and Pennsylvania farmers are listed.

467 S INCORPORATION OF SEWAGE SLUDGE IN SOIL TO MAXIMIZE BENEFITS AND MINIMIZE HAZARDS TO THE ENVIRONMENT
Agricultural Research Service
U.S. Dept. Agr., Beltsville, Maryland, 1972. 118 p.

Descriptors: Sludge disposal, Pathogenic bacteria, Maryland, Groundwater contamination, Soil chemical properties.

The principal objective of the project is to conduct a pilot study on land of the ARS at Beltsville, Maryland, on incorporation of sewage sludge in agricultural land by a trenching method. Work includes different depths and spacing of trenches, different sludges and different management of the land after incorporation of sludge. Supplemental tests will be made on other methods of sludge application. Evaluations will include physical and logistical problems in the operation, effects on quality of groundwater, plant growth and nutrient uptake, survival and movement of pathogens, and effect on soil properties. Research is also being conducted in greenhouses and laboratories on the chemistry, microbiology and behavior in soil of different kinds of sewage sludges.

468 M NORTH TAHOE AGENCIES TEST DISPOSAL IN VOLCANIC CINDER CONE

Allen, M. L.

Bull. Calif. Water Pollut. Contr. Ass., 9(3): 31-38, January 1973.

Descriptors: Deep percolation, Primary effluent, Monitoring, Wastewater disposal, California.

Faced with exporting wastewater from the Tahoe Basin watershed in 1968, Tahoe City PUD and the North Tahoe PUD joined forces and decided upon land disposal of effluent by percolation as the most promising alternate. The 2.8 mgd of primary effluent was disposed of in some 43,000 feet of trenches at the top of Cinder Cone some 3 miles away. There were 13 monitoring stations established to sample springs, outcroppings, and the Truckee River. There was an increase in chloride concentration at one station from a background level of 1-2 mg/l to 15 mg/l. This occurred 5 months after the beginning of operations and required the development of an alternate source of water for one family. Although this disposal method has been successful, it is only temporary and will be abandoned in 1976 when a regional sewerage project is completed.

469 M THE COST OF A SPRAY IRRIGATION SYSTEM FOR THE RENOVATION OF TREATED MUNICIPAL WASTEWATER

Allender, G. C.

Master's Thesis, The Penn. State Univ., September 1972.

Descriptors: Costs, Penn State, Pennsylvania, Sprinkler irrigation, Rates of application, Wastewater disposal.

The study reviewed and summarized the various parameters affecting the design of a spray irrigation system. On the basis of data collected, a method was developed to determine the capital and operation and maintenance cost of a spray irrigation system for the disposal of effluent from a municipal wastewater treatment plant. The method consists of sizing individual distribution and transmission units of the spray irrigation system. The study concluded that (1) the use of spray irrigation is primarily dependent upon the suitability of the soil and the availability of land, (2) 2 inches per week of loading rate and 1/6 inch per hour of application rate seem to be most desirable, (3) a maximum spacing of 105 feet between sprinklers in the field often is desirable to provide an even distribution, (4) the cost of spray irrigation per equivalent dwelling unit and per 1,000 gallons will increase rapidly below total waste flows of 1 mgd.

470 S ENRICHMENT OF TRACE ELEMENTS FROM SEWAGE SLUDGE FERTILIZER IN SOILS AND PLANTS

Anderson, A., and K. O. Nilsson
AMBIO (Oslo, Norway), 1(5): 176-179, September/October 1972.

Descriptors: Sweden, Recycling nutrients, Soil chemical properties.

This paper reports on trace element analyses of soil and vegetation from a field trial where one of the treatments has received sewage sludge as a source of plant nutrients, five received no form of organic substance, but received varying amounts of chemical fertilizers, and nine received organic substance other than sewage sludge and chemical fertilizers.

471 M ENGINEERING REPORT ON IMPROVEMENT AND EXPANSION OF WASTEWATER TREATMENT FACILITIES FOR THE CITY OF MARSHALL, MINNESOTA

Banister, Short, Elliott, Hendrickson and Associates
St. Paul, Minnesota, November 1971.

Descriptors: Minnesota, Design data, Sprinkler irrigation, Winter storage, Rates of application.

The use of irrigation for sewage effluent is contemplated, the biggest advantage being the stopping of pollution in the local river. However, due to the short irrigation period during warm weather, and the poor drainage of land in this area, many problems are foreseen. Land estimates for 2 mgd in 1976 are about 1,000 acres, plus a stabilization pond capable of holding six months' effluent.

472 M GROUND WATER POLLUTION IN ARIZONA, CALIFORNIA, NEVADA AND UTAH

Barton, James R., and Dean K. Fuhriman
U.S. Environmental Protection Agency, Washington, D.C., Report No. 16060 ERU 12/71, December 1971. 255 p.

Descriptors: Southwest U.S., Salinity, Nitrate contamination, Groundwater contamination, Spreading basins.

The discussion of polluted ground waters includes a discussion of agricultural derived pollution and pollution from spreading basins. The authors state that irrigation causes pollution by salts while spreading basins are generally nonpolluters but instances of nitrate pollution have been noted. It is also noted, however, that the dumping of sewage and other wastes into streams, lakes and other bodies of water is also a major source of groundwater pollution.

473 M MANAGING THE MOVEMENT OF WATER THROUGH SOILS AND AQUIFER

Bauer, W. J., and J. Sheaffer
Presented at 45th Annual Conf. Water Pollut. Contr. Fed., Atlanta, Ga., October 8-13, 1972.

Descriptors: Tile drainage, Heavy metals, Viruses, Illinois, Groundwater movement.

The early settlers of Illinois passed much potential farmland by because it was swampy. With drainage pipes, ditches, and sometimes pumps, later immigrants turned these neglected acres into some of the most productive farms of the Midwest. These same drainage practices and the principles underlying them can be used to manage the movement of irrigated wastewater through the soil and the aquifers beneath.

This paper discusses methods of controlling the quality of groundwater and the direction of its movement, of preventing salt buildup in the soil and in the groundwater, of removing heavy metal and viral pathogens from the water, of evaluating the economics of land treatment of wastewater in comparison with other systems of wastewater treatment, of enhancing the value of the land treatment system by siting nuclear power plants at wastewater irrigation sites, and of acquiring the land needed for land disposal systems and relocating families whose homes are affected by the irrigation.

474 M STUDY OF REUTILIZATION OF WASTEWATER RECYCLED THROUGH GROUNDWATER, VOLUME 1

Boen, D. F., J. H. Bunts, Jr., and R. J. Currie
U.S. Environmental Protection Agency, Washington, D.C., Report No. 16060 DDZ, July 1971. 190 p.

Descriptors: California, Monitoring, Activated sludge effluents, Rates of application, Groundwater recharge.

The Hemet-San Jacinto Valley, California, is a closed basin which is dependent in part upon imported water. A six and a half year study concludes, among other things:

(1) By 1980 sufficient wastewater will be available to recharge a total of 10,500 acre feet/year;

(2) Recharge of groundwater aquifers will result in reducing the basin's water deficit and the importation of Colorado River water with its high mineral content; and

(3) There is no evidence, during this short-time period, of any degradation of the groundwater quality in the water-producing strata in the Upper San Jacinto Groundwater Basin. A more general conclusion is that water reclamation is an important source of water and should be included in any water management planning within a closed basin.

The project added considerable knowledge and experience to the technology of intermittent wastewater percolation and associated monitoring techniques. A novel feature of the project was the use of highly sensitive temperature probes to trace lateral migration of the recharged water. It appears that much of the recharged water is escaping as shallow underflow to the San Jacinto River and, therefore, is not reaching the deep groundwater table.

475 M NITRATE AND NITRITE VOLATILIZATION BY MICROORGANISMS IN LABORATORY EXPERIMENTS

Bollag, Jean-Marc

U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA-660/2-73-002, August 1973. 65 p.

Descriptors: Anaerobic conditions, Denitrification, Wastewater disposal, Biodegradation, Recycling nutrients.

Microbial nitrate and nitrite volatilization was considered as a means to eliminate nitrogen from soil and water in order to inhibit the accumulation of nitrogenous substances as pollutants or health hazardous compounds. Therefore it was attempted to compare nitrate-reducing microorganisms in their reactions to different environmental conditions in laboratory experiments. Changing oxygen concentration, pH, temperature, nitrate or nitrite concentration affected differently the denitrification process of various isolated microorganisms. Unfavorable growth conditions led to the accumulation of nitrite if nitrate served as substrate. It was found that certain soil fungi are also capable of volatilizing nitrogen as nitrous oxide. Biological and chemical factors were evaluated during nitrite transformation in autoclaved and non-autoclaved soil by determination of the evolvement of nitrogenous gases. During chemical nitrite volatilization, which occurred essentially at a low pH, the major gases evolved were nitric oxide and nitrogen dioxide, but if biological activity was predominant in a neutral and alkaline environment, nitrous oxide and molecular nitrogen were formed. The validity of laboratory observations in relation to field studies in the domain of denitrification is discussed and evaluated.

476 M RENOVATING SECONDARY EFFLUENT BY GROUNDWATER RECHARGE WITH INFILTRATION BASINS

Bouwer, H.

In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 164-175.

Descriptors: Groundwater recharge, Coliforms, Phosphorus removal, Denitrification, Phoenix, Arizona.

Secondary effluent from the 91st Avenue treatment plant in Phoenix, Arizona, has been renovated on a pilot scale by rapid infiltration into the groundwater. Maximum rates of 350 to 400 ft per year were achieved by spreading for 2 weeks and resting 10 days in summer and 20 days in winter.

The pilot plant was located in the Salt River bed where the soil is a sandy loam and the groundwater is at a depth of 10 ft. Observation wells for sampling renovated water were installed inside and outside the basin area.

Suspended solids, fecal coliform and BOD were essentially completely removed by percolation through 30 ft of soil. About 70% of the phosphorus and fluorides were removed.

Overall nitrogen removal is difficult to predict but appears to be about 30% with the loading schedule described. Boron, lead, and cadmium were not removed.

477 M RENOVATING SECONDARY SEWAGE BY GROUND WATER RECHARGE WITH INFILTRATION BASINS

Bouwer, H., R. C. Rice, and E. D. Escarcega

U.S. Environmental Protection Agency, Washington, D.C., Report No. 16060 DRV 03/72, March 1972. 103 p.

Descriptors: Phoenix, Arizona, Phosphorus removal, Groundwater recharge, Spreading basins, Costs.

The results of the Flushing Meadows, Arizona, field project demonstrated the feasibility of renovating secondary sewage effluent by groundwater recharge with infiltration basins. Maximum loading rates were obtained with cycles of 20 days' flooding rotated with dry periods of 10 days in the summer and 20 days in winter. With these schedules, the system could infiltrate 300-400 ft/year using a water depth of 1 ft. Grassed basins had higher infiltration rates, and a gravel covered basin had a lower infiltration rate than a bare soil basin. Essentially complete removal of BOD and fecal coliform, and significant removal of phosphorus, nitrogen and fluoride were obtained. Hydraulic *properties of the aquifer were evaluated by analog from the response of piezometric heads in the groundwater system to infiltration. These properties were then used in the design of a prototype system, which would yield renovated water at an estimated total cost of about $5 per acre-foot at the pump.*

478 M USING RECLAIMED WASTEWATER--PUBLIC OPINION
Bruvold, W. H., and P. C. Ward
J. Water Pollut. Contr. Fed., 44: 1690, September 1972.

Descriptors: California, Surveys, Public acceptance, Water reuse.

Recognizing that water reclamation will become increasingly important, the authors noted that public opinion could be a large factor influencing its future use and that public opinion was not known. In a sampling of 10 California cities--six from northern California and four from southern California--public opinion on wastewater reclamation and use was obtained. Picking the southern and northern cities from the same socioeconomic classes, it was found that public opinion in the two regions does not differ appreciably. The greatest opposition was noticed for the reuse of water as drinking water, the least opposition was found for reclamation of water for road construction. As the possibility for personal contact with reclaimed water increased, so did public opposition.

479 M GROUNDWATER LAW, MANAGEMENT AND ADMINISTRATION
Corker, Charles E., and J. W. Crosby, III
National Water Commission Report (Legal Study No. 6), L-71-026, October 1971.

Descriptors: Reviews, Geohydrology, Groundwater recharge, Legal aspects, United States.

This report describes groundwater hydrology, emphasizing the importance of recognizing the interrelation of ground and surface water supplies. It then describes the legal doctrines applicable to the use of groundwater, noting the differences among the states and the departure of law from scientific fact. It identifies the major problems of groundwater law and suggests solutions. In considering groundwater management, it sets forth criteria for judging management proposals, concluding with a consideration of constitutional limitations. The problem of groundwater mining is dealt with.

480 M WASTEWATER TREATMENT STUDY, MONTGOMERY COUNTY, MARYLAND, VOLUME I
Cornell, Howland, Hayes and Merryfield
Clair A. Hill and Associates, November 1972. 317 p.

Descriptors: Maryland, Wastewater treatment, Wastewater disposal.

Relates results of detailed study of five advanced wastes treatment (AWT) sites, four in Montgomery County and one near Dickerson, Maryland, on the Potomac Electric Power Company (PEPCO) property, and the various treatment processes available, including land disposal. Alternatives at the PEPCO site include AWT at that site; AWT at a lower basin site, with clear water transmitted to PEPCO; and land disposal in conjunction with PEPCO use of partially-treated wastewater. Report recommends treatment processes but not the site.

481 M WASTEWATER MANAGEMENT PROJECT, MUSKEGON COUNTY, MICHIGAN
Davis, G. W., and A. Dunham
Univ. of Chicago, Center for Urban Studies, Il, 1971. 322 p. (Also NWC-SBS-72-38)

Descriptors: Planning, Wastewater treatment, Muskegon, Michigan, Sprinkler irrigation.

This report is a case study of one particular regional planning effort which was innovative in concept and which has been politically and administratively implemented. This is a study of the Muskegon County, Michigan Wastewater Management System, popularly known as The Muskegon Spray Irrigation Project.

482 M FACTORS AFFECTING BIOLOGICAL DENITRIFICATION OF WASTEWATER
Dawson, R. N., and K. L. Murphy
In: Advan. Water Pollut. Res., Proc. Int. Conf. 6th, Jerusalem, June 18-23, 1972. New York, Pergamon Press, 1973. p. 671-680.

Descriptors: Denitrification, Activated sludge effluents, Biodegradation, Rates of application.

A study was undertaken to determine the relative importance and interactions between variables affecting the unit denitrification rate. Findings indicate that the rate is independent of carbon and nitrate concentration, providing sufficient organic carbon is added to satisfy the nitrate reduction and organism growth. The optimum pH for *denitrification with Pseudomonas denitrificans appears to be 7.0, the pH level usually attained in biological waste treatment processes. Activated sludge from an extended aeration plant denitrified at 27° C as if 20-25 percent by weight were composed of organisms with an equivalent unit nitrate reduction rate as P. denitrificans. The unit denitrification rate of P. denitrificans can be approximated by an Arrhenius type of temperature dependency between 3° C and 27° C. At 5° C, the unit rate was sufficiently high to allow use of this process if stirred tank detention times of three to eight hours and higher organism population (5,000 mg/l) are used.*

483 M EFFECTS OF TREATMENT PLANT EFFLUENT ON SOIL PROPERTIES

Day, A. D., et al.
J. Water Pollut. Contr. Fed., 44: 372-375, March 1972.

Descriptors: Soil chemical properties, Soil types, Salinity, Tucson, Arizona.

Recognizing that water supplies are becoming harder and harder to find, sewage effluent is becoming more and more popular as a source of irrigation water. Long-term studies of the effects of effluent on soil condition are lacking; this is the purpose of this study. Comparing Grabe silt irrigated with effluent to soil which has been fertilized at recommended rates, shows that the effluent-irrigated soil has higher concentrations of soluble salts, nitrates, phosphates, calcium and magnesium than the control. Organic material was greater in the control. No declines in crop yield or adverse effects on the soil were recorded.

484 M CALIFORNIA WATER RECLAMATION SITES

Deaner, D. G.
Bur. Sanit. Eng., Calif. State Dept. Pub. Health, Berkeley, June 1971.

Descriptors: California, Geohydrology, Wastewater treatment, Surveys.

This report contains information regarding California water reclamation sites in existence in 1971. The reclamation operations are grouped by the major hydrologic basins and subbasin of California. The information given in the report consists of the amount of water reclaimed and used for crop irrigation, and the type of pretreatment given at each facility.

485 M FINAL REPORT ON IMPACT ASSESSMENT AND EVALUATION OF WASTEWATER MANAGEMENT ALTERNATIVES, CLEVELAND-AKRON METROPOLITAN AND THREE RIVERS WATERSHED AREAS (APPENDIX III)

Dee, Norbert, et al.

U.S. Army Corps Eng., Buffalo District, Battelle Columbus Laboratories, 1971. 132 p.

Descriptors: Wastewater treatment, Planning, Ohio, Water management (applied).

Impacts were assessed for the wastewater treatment alternatives of water and land, and a combination thereof. To stress the important water resource objectives of environmental quality, social well-being, regional development and national economic development and at the same time to bring to the surface the major impacts, an Impact Matrix was used. The water alternative is expected to produce both beneficial and adverse impacts but was primarily beneficial in nature. However, the land and the combination alternatives were significantly adverse in nature. This evaluation is specific to the alternatives given the research team and is not a general evaluation of all water, land or combination plans.

486 I DAIRY FOOD PLANT WASTES AND WASTE TREATMENT PRACTICES

Department of Dairy Technology, Ohio State Univ.

U.S. Environmental Protection Agency, Washington, D.C., Report No. 12060 EGU 03/71. March 1971. 559 p.

Descriptors: Reviews, Sprinkler irrigation, Clogging (soil), Dairy wastes, Furrow irrigation.

Using an extensive literature search, spray irrigation and ridge and furrow irrigation of dairy wastes are discussed. Although many operations have been successful, some have failed due to odors, ponding, runoff, loss of cover crop and soil clogging. Even successful operations are still in experimental stages as long-term effects on crops, soil and water supplies are not known. Tables of current practices of about 60 dairy operations using land disposal are presented.

487 M SOIL FILTRATION OF WASTEWATER EFFLUENT AND THE MECHANISM OF PORE CLOGGING

DeVries, J.

J. Water Pollut. Contr. Fed., 44: 565-573, April 1972.

Descriptors: Primary effluent, Phosphorus removal, Rates of application, Clogging (soil).

Primary wastewater treatment plant effluent was applied to sand filters at room temperature for 2 hr daily for 240 days at a rate of 20 cm/day, 5 days/wk, with filters being drained between applications. No physical deterioration of the filters occurred. However, the same pattern of application at 4° ± 3°C resulted in failure in 10 days. Failure was caused by sealing of surface pores. At room temperature, the failed filters recovered in about 8 days, apparently because of disruption of the sludge layer. The fine sand filter removed nearly all the biochemical oxygen demand and phosphate, but the reductions in the medium sand filter were about 70 and 10 percent, respectively. Both filters removed about 25 percent of effluent nitrate.

488 M EFFECT OF SEWAGE IRRIGATION ON THE FERTILITY OF SOD PODZOLIC LOAMY-SAND SOILS

Dodolina, V. T.
Pochvovedenie (Moscow), 76: 65-73, 1971.

Descriptors: Flood irrigation, Soil types, Forage crops, Soil chemical properties, Soviet Union.

Results are given of 5 years of sewage irrigation of sod podzolic soils under perennial grass. The humus content increased 0.2% and the total N increased 0.02%-0.03%. A decrease in the potential and hydrolytic activities and an increase in the structure were also found. The yield of grasses increased 1.5 to 2.0-fold over those irrigated with water.

489 M RACETRACK SEWAGE PLANT SOLVES DIMMITT'S SANITATION PROBLEMS

Ebly, Jean
Water Sewage Works, 120: 302-303, September, 1971.

Descriptors: Texas, Rates of application, Flood irrigation, Operation and maintenance, Aerated lagoon effluents.

Dimmitt, Texas pumps 400,000 gpd of sewage effluent to farmlands for use in irrigation. Maintenance is minimal, just routine cleaning and greasing of pumps.

490 M THE SOIL AS A CHEMICAL FILTER

Ellis, B. G.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 46-70.

Descriptors: Ion exchange, Phosphorus removal, Heavy metals, Soil chemical properties.

Ion exchange reactions will occur, both cation and anion, which will alter the composition of the water during the time it is in contact with the soil profile. In general, it is expected that wastewater will be higher in monovalent cations than natural soil systems. The exchange of divalent by monovalent ions in the soil can lead to a more dispersed system and in many instances reduced infiltration rates.

Soils are known to be able to adsorb from less than 1,000 to more than 3,000 pounds of phosphorus per acre to a depth of three feet. This mechanism offers an effective means of removing phosphorus from wastewaters and fixing phosphorus applied in sludge. But it does have limits and if overloaded the soil will cease to remove phosphorus. Although less studied, similar mechanisms of adsorption are expected to remove some sulfate, boron, and heavy metals from wastewater and sludge. It is difficult to distinguish physically between adsorption and precipitation but, in general, it would be expected that precipitation reactions would occur after adsorption reactions had reached completion. Many elements will precipitate as insoluble hydroxides, carbonates or other compounds in soils. Precipitation reactions will usually be very dependent upon soil pH. Compounds which are precipitated may be brought back into solution by either a change in pH or by the presence of chelators, either natural or synthetic. The level of many heavy metals in solution may be limited by the precipitation of their hydroxides.

491 S THE GIVE AWAY MARKETEERS
Gaffney, M. P.
May 1972. 16 p.

Descriptors: Hertfordshire, England, Soil chemical properties, Heavy metals.

A description of the land application of digested sludge by the West Hertfordshire Main Drainage Authority, England. Sludge, called Hydig, is distributed over a 300-square-mile radius by the district without charge. Control of heavy metals is mentioned, as well as the development of a "zinc-equivalent," to express the relative buildup of metals.

492 I A SPRAY IRRIGATION SYSTEM FOR TREATMENT OF CANNERY WASTES
Gilde, L. C., et al.
J. Water Pollut. Contr. Fed., 43: 2011-2025, August 1971.

Descriptors: Food processing wastes, Paris, Texas, Microbial degradation, Tertiary treatment, Overland flow.

This study presents the results obtained from the 12-month research program conducted by Campbell Soup Company at Paris, Texas. The study was conducted for the purpose of learning more about the microbiology, microclimate, forage quality, yield, and treatment efficiency of the spray runoff system. The results show that the microbial population varies between 500 and 600×10^6 organisms/gram of soil and that, on the average, about 6 times as many organisms are present in treated as in untreated soils. Of the organisms selected for the evaluation, the aerobioheterotrophic bacteria and streptomyces account for over 90 percent of the population. The results also show that the irrigation system equals or betters tertiary treatment, with an average reduction of more than 99 percent in BOD while also accomplishing major reductions in nutrients. The system represents an excellent soil conservation practice of converting badly eroded, nonusable farmland into uniform slopes and terraces for treatment purposes.

493 M EFFECT OF DISSOLVED SALTS ON THE FILTRATION OF COLIFORM BACTERIA IN SAND DUNES

Goldshmid, J., et al.
In: Advan. Water Pollut. Res., Proc. Int. Conf. 6th, Jerusalem, June 18-23, 1972. New York, Pergamon Press, 1973. p. 147-155.

Descriptors: Coliforms, Dissolved solids, Israel, Aerated lagoon effluents, Salinity.

The plans for the Dan Sewage Reclamation Project call for infiltration through sand dunes followed by a 400-800 day lag period, as the final treatment step, before pumping the reclaimed sewage from the aquifer into the drinking water supply. The work described here elucidates the effect of concentration and composition of dissolved salts in the treated effluent on the filtration efficiency of coliform bacteria in sand dunes. It was concluded that an increase in cation concentration and valence increases filtration efficiency of coliform bacteria through sand dune. In the presence of oxidation pond effluents more cations are required to achieve the same filtration efficiency. Bacterial balance showed that bacteria stay alive even after being attached to sand particles. No agglomeration of bacteria was observed in the concentration range tested in these experiments. A decrease of pH from 9.3 to 3.9 increased filtration efficiency. The effect of cation concentration on filtration efficiency is reversible. A decrease in cation concentration of the same valence will filter out bacteria which had already been removed.

494 I SPRAYFIELD APPLICATION HANDLES SPENT PULPING LIQUORS EFFICIENTLY

Guerri, E. A.
Pulp Pap., 45(2): 93-95, 1971.

Descriptors: Indiana, Rates of application, Suspended solids, Soil physical properties, Pulp and paper wastes.

The Terre Haute, Indiana mill of the Weston Paper and Manufacturing Co. is disposing of spent sodium base cooking liquor on land. The high sodium content (16.4 percent of the dry solids) and high temperature (185° to 195° F) at which the waste is sprayed preclude any cover crop. The 200,000 gpd containing 11.3 percent solids is applied at an average rate of 0.44 in./wk. This method has been successful in preventing runoff from the 120 acres of wetted field. As the sodium content eventually destroys the structure of the soil, a plot must be rejuvenated by loading with gypsum and growing a cover crop for several years.

495 S AGRICULTURAL BENEFITS AND ENVIRONMENTAL CHANGES RESULTING FROM THE USE OF DIGESTED SEWAGE ON FIELD CROPS, AN INTERIM REPORT ON A SOLID WASTE DEMONSTRATION PROJECT

Hinesly, T. D., O. C. Braids, and J. E. Molina
Metropolitan Sanit. District of Greater Chicago, Il. U.S. Environmental Protection Agency, Washington, D.C., 1971. 73 p.

Descriptors: Chicago, Illinois, Coliforms, Anaerobic digestion, Rates of application, Aerobic digestion.

The Metropolitan Sanitary District of Greater Chicago worked with the University of Illinois to test the use of digested sewage sludge on farm land. Crop response, chemical pollution of runoff and the possibility of contamination by fecal coliform were studied. It was found that freshly digested sludge had serious agricultural disadvantages, inhibiting seed germination. In some cases, germination fell to zero, while other tests showed germination of other seed types at only 30 percent of normal. Aging or aeration of the sludge corrected this problem. Similarly, fecal coliform counts were high in freshly digested sludge and fell rapidly upon aging. Sludge was found to be infiltrated very slowly into the ground, and application rates must be kept low to avoid runoff of sludge from slopes. Crops raised on sewage sludge produced better yields than the control crops and did not show any absorption of toxic heavy metals found in the sludge.

496 S PROBLEMS OF SLUDGE TREATMENT AND DISPOSAL
Horner, R. W.
In: Proc. Inst. Civil Eng. (London), 49:87-90, 1971.

Descriptors: Wastewater treatment, Sludge disposal, Reviews, United States.

Mr. Horner described sewage treatment as predominantly a concentration process in which each stage and type of treatment produced its own particular concentrated pollutant. The main problem, however, was the treatment and disposal of the sludges produced by the primary, secondary, and tertiary treatment processes. A very wide range of processes had been employed, with varying degrees of success, in their treatment and disposal.

497 M THE USE OF THE SOIL AND ITS ASSOCIATED BIOSYSTEMS TO RECYCLE URBAN INDUSTRIAL AND AGRICULTURAL WASTES
Kardos, Louis T.
APWA Reporter, May 1973. 13 p.

Descriptors: Sprinkler irrigation, Soil chemical properties, Penn State, Pennsylvania, Soil physical properties, Soil microbiology.

Author's thesis is that use of the land and its associated biosystems, rather than surface waters, as an extensive recycling system enables one to utilize the strong physical, chemical and biological buffering capacity of the soil in relieving various kinds of water pollution crises. Pertinent aspects of the Penn State living-filter project are discussed. Present research at Penn State, in which final digested sludge from the treatment plant is injected into the wastewater pipe line and applied through the sprinklers, indicates that the same acres being used for the wastewater disposal can take care of the sludge disposal in a totally integrated operation without unbalancing the living-filter system.

498 M RENOVATION OF MUNICIPAL WASTEWATER THROUGH LAND DISPOSAL BY SPRAY IRRIGATION
Kardos, L. T., and W. E. Sopper
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 148-163.

Descriptors: Phosphorus removal, Penn State, Pennsylvania, Wastewater treatment, Nitrification, Rates of application.

Both cropland and forest areas receiving two inches of effluent at weekly intervals have continued to show an excellent capacity for removing phosphorus, with better than 99% reduction of phosphorus concentration in the recharging renovated wastewater. Total nitrogen concentrations have decreased better than 75% with silage corn and better than 93% with reed canarygrass. Forested areas receiving one inch of effluent at weekly intervals have diminished nitrogen concentrations by 61% to 85% but where two inches of effluent was applied at weekly intervals inadequate nitrogen removals occurred at about the fifth year on the fine textured soil and at about the third year on the sandy soil. On an old field site with a scattering of white spruce, which received two inches at weekly intervals, nitrogen concentrations diminished by 78% to 88%.

In 1970, on the reed canarygrass area where 545 pounds of nitrogen was added during the year, water samples at four foot depth had an average annual concentration of only 2.3 mg/l. Where two inches of effluent has been applied weekly, average annual nitrate-nitrogen concentrations in the silage corn area have climbed to 11.7 mg/l in 1970, in the red pine forest to 17.7 mg/l in 1969, in the hardwood forest on a sandy soil to 33.3 mg/l in 1970 but in the old field area only to 3.5 mg/l in 1970. In the hardwood forest on a silt loam soil where four inches of effluent was applied weekly for five years the nitrate level at 48 inches remained below 10 mg/l, the U.S. Public Health Service recommended limit for potable water.

499 M WATER SUPPLY FROM RENOVATED WASTE WATER
Kasperson, Roger E., and Marc Eichen (ed.)
1972. 207 p.

Descriptors: Bibliographies, Public acceptance, Massachusetts, Wastewater treatment, Planning.

A resource manual for Massachusetts planners, public officials and citizens groups. It deals with four major issues: (1) placing water reuse in a larger context; (2) the major problem areas in wastewater renovation for water supply, including public acceptance; (3) the relevant experiments at Windhoek, South Africa, Santee and Lake Tahoe, California; and (4) the outlook for Massachusetts. Each section concludes with an annotated bibliography.

500 M SEWAGE TREATMENT FARMS
Kirby, C. F.
Dept. Civil Eng., Univ. of Melbourne, 1971.

Descriptors: Melbourne, Australia, Rates of application, Wastewater treatment, Operation and maintenance, Water quality data.

This paper outlines three methods of treating the wastewater from the city of Melbourne, Australia: land filtration, grass filtration, and lagooning. Grass filtration is notable because it is the only known application of the overland flow technique to municipal wastewater on a full scale.

Overland flow is used in place of irrigation for the six month winter periods. The loading rate is 20,000 gad using Italian rye grass for filtration. The wastewater is applied by border check irrigation. Estimated removals are as follows: BOD, 96 percent; SS, 95 percent; nitrogen, 60 percent; phosphorus, 35 percent; E. coli, 99.5 percent; detergent, 50 percent.

The design loading rate is approached gradually over a period of two to three weeks. Some settlement of suspended matter occurs at the tops of the bays, where the water is admitted, and creates an anaerobic condition, which extends for some distance down the bays before aerobiosis begins.

501 S DO ORGANIC WASTES BELONG ON THE LAND?
Kolb, J.
Compost Sci., 13(1): 14, January-February 1972.

Descriptors: Sludge disposal, Soil contamination.

Report on Solid and Water Conservation. Division of the U.S. Department of Agriculture which states that the Nation's land resources will be in no danger from using them for waste disposal.

502 S EXPERIENCES WITH THE SLUDGE PROGRAM IN THE DENVER AREA
Korbitz, W.
Compost Sci., 12(5): 3-5, September-October 1971.

Descriptors: Reviews, Sludge disposal, Planning, Colorado.

The report shows the Metro Denver District staff is firmly convinced that "future sewage sludge must be recycled to the land."

503 M NITROGEN REMOVAL BY SOIL MECHANISMS
Lance, J. C.
J. Water Pollut. Contr. Fed., 44: 1352-1361, July 1972.

Descriptors: Denitrification, Nutrient removal, Soil chemical properties, Phoenix, Arizona.

Land disposal removes nitrogen from wastewater by denitrification, volatilization of ammonia, and removal of plant tissue grown on the disposal site. Denitrification is the most desirable removal process because nitrogen is transferred to the atmosphere as gaseous nitrogen without causing air pollution. Large quantities of nitrogen can be stored in the soil in various forms but not indefinitely. The nitrogen of wastewater can also be concentrated into smaller volume of reclaimed water than can be further treated or used for fertilizer.

504 M NITROGEN BALANCE IN SOIL COLUMNS INTERMITTENTLY FLOODED WITH SECONDARY SEWAGE EFFLUENT
Lance, J. C., and F. D. Whisler
J. Environ. Quality, 1(2): 180-186, April-June 1972.

Descriptors: Nitrification, Denitrification, Phoenix, Arizona, Soil physical properties, Rates of application.

The sampling wells at the Flushing Meadows project in Phoenix, Arizona have produced renovated water with occasionally high nitrate concentrations. Because it is difficult to predict the volume represented by these samples, a physical model of the filtration system was constructed in the laboratory. Six PVC columns were filled with soil from the Salt River bed and dosed with secondary sewage effluent containing 25 mg/l of ammonia nitrogen.

Short, frequent floodings of the soil columns (2 days flooded and 5 days dry) caused no net removal of nitrogen but produced nearly complete nitrification. The net nitrogen removal during longer cycles (9-23 days flooded and 5 days dry) was 30 percent. Half of the nitrogen that remained in the renovated water was contained in the wave of high-nitrate water, which represented 10 percent of the total volume of renovated water and was collected immediately after the dry period. After the wave of high nitrate passed, net nitrogen removal was 67 percent.

505 M REACTIONS OF HEAVY METALS WITH SOILS WITH SPECIAL REGARD TO THEIR APPLICATION IN SEWAGE WASTES
Leeper, G. W.
U.S. Army Corps Eng., November 1972. 70 p.

Descriptors: Soil chemical properties, Heavy metals.

The heavy metals are listed, along with general statements about them. The fate of heavy metals in soils, as well as the mechanisms of removal of individual or grouped heavy metals is discussed. There are sections on prehistoric pedology and uptake of heavy metals by plants.

506 M UNDERGROUND TRAVEL OF POLLUTANTS
Mathur, R. P., and N. S. Grewal
In: Advan. Water Pollut. Res., Proc. Int. Conf. 6th, Jerusalem, June 18-23, 1972. New York, Pergamon Press, 1973. p. 159-166.

Descriptors: Groundwater contamination, Groundwater movement, Groundwater recharge, Soil physical properties.

Deals with limitations of returning wastewaters underground, taking advantage of the filtering ability of the soil and the diluting effect of groundwater. Study attempts to show how wastewater is likely to travel after its introduction into groundwater. A model study of dispersion of organic matter in the form of synthetic sewage has been made. The parameters selected were organic matter (oxygen consumed by the $KMnO_4$ test) and the Enterococcus group of bacteria.

507 M WASTE INTO WEALTH
Melbourne and Metropolitan Board of Works
Melbourne, Australia, 1971. 16 p.

Descriptors: Melbourne, Australia, Soil types, Costs, Flood irrigation, Overland flow.

The Board of Works farm at Werribee, Australia has received the untreated sewage from Melbourne since 1892. Covering 26,800 acres in an area of high evaporation (45 inches per year) and low rainfall (19 inches per year), it is one of the largest wastewater treatment farms in the world. The farm is stocked with up to 19,000 beef cattle and up to 50,000 sheep.

Three treatment methods are utilized depending on the time of the year and the flow. During the summer, most of the 114 mgd average daily flow is used to irrigate 10,376 acres of pasture. The water is applied by flooding a confined area which has an underground drain system for disposal of about 1/3 of the water. Depending on the soil, which is mostly a clay loam, loading rates range from 4,000 to 5,500 gpd per acre (1-1.4 in./week).

During the cold weather, overland flow through Italian rye grass is the method of treatment. The treated effluent is collected in surface drains and discharged into Port Phillip Bay. The loading rate on these 3,472 acres is 21,000 gpd per acre (0.77 in./day). Excess flows and storm flows (up to 2[illegible]0 mgd) are treated in 3,393 acres of lagoons, where the detention time is over 6 weeks, prior to discharge. Net cost of treatment and disposal is $1.07 per capita served based on 1.8 million people or $56 (U.S. currency) per million gallons.

508 M WASTEWATER ENGINEERING
Metcalf & Eddy, Inc.
New York, McGraw-Hill Book Company, 1972. 782 p.

Descriptors: Golf courses, Groundwater recharge, Rates of application, Tertiary treatment.

Reuse applications of effluent include crop irrigation, golf course and park watering, and groundwater recharge. Examples of the latter two uses are cited. A table of application rates for various methods, types of wastewater, and soil types is given. The amount of water that can be disposed of depends on the climatic conditions, the infiltration capacity of the soil, the types of crops or grasses grown, and the quality standards imposed where runoff is allowed.

509 M CONCENTRATION OF VIRUSES FROM SEAWATER
Metcalf, T. G., C. Wallis, and J. L. Melnick
In: Advan. Water Pollut. Res., Proc. Int. Conf. 6th, Jerusalem, June 18-23, 1972. New York, Pergamon Press, 1973. p. 109-115.

Descriptors: Viruses, Rates of application.

A flow-through system using textile filters was shown to be a feasible apparatus for the detection of viruses in large volumes of seawater. Field trials showed that the equipment could efficiently sample seawater at rates approaching 300 gallons per hour. Collection of virus upon these filters was shown to proceed without suffering significant loss of virus because of interference of absorption by membrane-coating *components. Laboratory trials conducted with artificial seawater demonstrated the ability of the virus concentration methods used to recover virtually all virus contained in the samples tested. The results obtained in field trials confirmed the laboratory findings and provided a new tool for detection of viruses in marine water.*

510 M GEOLOGICAL AND HYDROLOGICAL ASPECTS OF LAND TREATMENT OF WASTEWATER

Miller, D. W.
Presented at 45th Annual Conf., Water Pollut. Contr. Fed., Atlanta, Ga., October 8-13, 1972.

Descriptors: Geohydrology, Groundwater contamination, Wastewater treatment, Surveys.

The geology and hydrology of a particular site chosen for land treatment of wastewater can govern the success or failure of this process. Extensive studies of groundwater conditions should be undertaken to determine the impact of this method of wastewater treatment on the area involved in order to avoid such problems as contamination of underlying aquifers and troublesome rising groundwater levels. Of key importance is an understanding of the occurrence of groundwater in various geologic environments in addition to how the movement of waste fluids is affected by the configuration of the water table and the thickness and composition of the unsaturated zone.

After the treatment process has begun, the extent, thickness, direction and rate of movement of the wastewater body must be monitored. Geophysical surveys may be helpful in this connection by pinpointing highly mineralized groundwater.

511 S THE SOIL AS A BIOLOGICAL FILTER

Miller, R. H.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 71-94.

Descriptors: Soil microbiology, Biodegradation, Heavy metals, Nitrification.

The primary functions of the soil microbial component of the biological filter are as follows: (1) as a "decomposer" population metabolizing biodegradable organic materials to CO_2 and H_2O. The rate of this process often determines the loading rates and capacity of the soil for waste renovation. As part of this microbial reaction soil humic materials accumulate which are significant in modifying soil physical and chemical properties, (2) to degrade or detoxify potentially toxic or unwanted organic compounds, e.g., ABS, pesticides, NTA, phenols, etc., (3) to modify the adsorption and mobility of cations and anions including phosphorus and heavy metals within the soil profile, (4) to modify the adsorption of nutrient elements and heavy metals by plants associated with the soil filter. The mechanisms involved are oxidation-reduction, mineralization-immobilization, chelation and solubilization, (5) as the responsible agents for the nitrogen transformations necessary for the proper functioning of soil in waste renovation, e.g., immobilization-mineralization, nitrification and denitrification, and (6) in the elimination of pathogenic microorganisms.

512 S DIVISION S-3--SOIL MICROBIOLOGY AND BIOCHEMISTRY--AERATION-INDUCED CHANGES IN LIQUID DIGESTED SEWAGE SLUDGE

Molina, J. A. E., O. C. Braids, T. D. Hinesly, and J. B. Cropper
Soil Sci. Soc. Amer. Proc., 35:60-63, 1971.

Descriptors: Grain crops, Anaerobic conditions, Anaerobic digestion, Plant growth, Chicago, Illinois.

Explored the question of germination of corn and soybean seeds in the presence of liquid anaerobically digested sludge. Exposure of the sludge to the air resulted in ammonia losses, and inhibition of germination was not detected after a few days.

513 I REDUCES WASTEWATER TREATMENT COSTS 20-30%; SAVES ESTIMATED $2 MILLION CAPITAL EXPENSE

Morlock, J., et al.
Food Process., 34(1):52-53, 1973.

Descriptors: Food processing wastes, California, Spray disposal, Costs, Overland flow.

This description of the Hunt-Wesson Foods' overland flow facility at Davis, California, contains some error of fact. For instance, each bench is 175 ft wide and 800 ft long and by this description there are 84 benches. A design flow of 4.0 mgd is sprayed on 258 wetted acres. The initial capital cost was $1.25 million and annual costs range from $20,000 to $40,000 depending on the hay crop. A mixture of Reed canary, fescue, trefoil, and Italian rye grasses were sown. The screened tomato canning wastewater is delivered to the field through a pipeline 4 miles long.

514 M SPRINKLER IRRIGATION SYSTEMS
Myers, Earl A.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 324-333.

Descriptors: Penn State, Pennsylvania, Sprinkler irrigation, Rates of application, Design data, Climatic data.

Wastewater must be returned uniformly over the land surface at the proper rate in inches/hour and the appropriate amount in inches/week, if adequate renovation is to be expected. Penn State's 60-acre solid-set system which applies effluent at the rate of 1/16 inch/hour and two inches/week is discussed. Factors affecting the design of this system are considered, as well as variations in design for other soil, climatic, crop and effluent characteristics.

515 S RECYCLING MUNICIPAL SLUDGES AND EFFLUENTS ON LAND
National Association of State Universities and Land-Grant Colleges
Washington, D.C., July 1973. 244 p.

Descriptors: Reviews, Sludge disposal, Wastewater disposal, United States, Recycling nutrients.

This report contains 26 topical papers and the information gathered at a Research Needs Workshop co-sponsored by the National Association of State Universities and Land-Grant Colleges, the Environmental Protection Agency, and the United States Department of Agriculture.

516 I LIQUID WASTES FROM CANNING AND FREEZING FRUITS AND VEGETABLES
National Canners Association
U.S. Environmental Protection Agency, Washington, D.C., Report No. 12060 EDK, August 1971.

Descriptors: Sprinkler irrigation, Food processing wastes, Furrow irrigation, United States, Surveys.

Spray irrigation systems and ridge and furrow systems are briefly discussed, along with some requirements for operation. Ridge and furrow systems are being displaced by spray irrigation and it was estimated that, in 1965, there were 2,400 spray irrigation systems, 900 of these used by food processors. Percentages of canners using spray irrigation systems *are listed by the product processed. Corn processors used spray irrigation in 44 percent of the plants checked, pear canners were at the low end at 8 percent.*

517 M REVIEW DRAFT: PROPOSED REPORT OF THE NATIONAL WATER COMMISSION

National Water Commission
Washington, D.C. 1972.

Descriptors: Legal aspects, Water management (applied), Reviews, United States.

This comprehensive report discusses the following issues: (1) Water Supply and Water Use; (2) Water and the Natural Environment; (3) Water and the Economy; (4) Water Pollution Control; (5) Improving Water Related Programs; (6) Procedures for Resolving Differences over Environmental and Developmental Values; (7) Making Better Use of Existing Supplies; (8) Interbasin Transfers; (9) Means of Increasing Water Supply; (10) Better Decisionmaking in Water Management; (11) Improving Organizational Arrangements; (12) Water Problems of Metropolitan Areas; and (13) Federal-State Jurisdiction in the Law of Waters.

518 M COST OF SPRAY IRRIGATION FOR WASTEWATER RENOVATION

Nesbitt, J. B.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 334-338.

Descriptors: Sprinkler irrigation, Operation and maintenance, Rates of application, Costs, Penn State, Pennsylvania.

The cost of spray irrigation for wastewater renovation includes both capital and operation costs. Capital costs include the distribution system (irrigation pipe, risers, sprinkler heads, and fittings), equalization storage lagoon, pumping station, delivery system, land, site preparation, engineering and contingencies. Operating costs would include labor, power, and maintenance.

Assuming the above unit processes and some unit prices, the capital cost for systems of one, five and ten million gallons per day are, respectively, $439,000, $1,369,000, and $2,431,000. Annual costs for these systems (amortization plus operating costs) are $46,570, $146,340, and $263,060, respectively. These annual costs are equivalent to costs of 12.7 cents, 8.0 cents, and 7.2 cents per thousand gallons for each of the three flow rates.

519 M THE VIRUS PROBLEM IN THE WINDHOEK WASTEWATER RECLAMATION PROJECT
Nupen, Ethel M., and G. J. Stander
In: Advan. Water Pollut. Res., Proc. Int. Conf. 6th, Jerusalem, June 18-23, 1972. New York, Pergamon Press, 1973. p. 133-142.

Descriptors: Planning, Coliforms, Aerated lagoon effluents, South Africa, Viruses.

Intensive plan is described for monitoring and control of Windhoek Wastewater Reclamation Plant. It included virological testing of settled sewage entering the Gammams Sewage Purification Works and the final maturation pond effluent from the works which constituted the intake to the Windhoek Plant. Also, all other sources of water supplied to the area were routinely checked for virus and fecal contamination.

520 M NEW DIRECTIONS FOR WASTEWATER COLLECTION AND DISPOSAL
Okun, Daniel A.
J. Water Pollut. Contr. Fed., 43: 2171-2180, November 1971.

Descriptors: Los Angeles, California, Deep percolation, Economic feasibility, Water reuse.

In 1938, the effluent from the Pasadena plant was being discharged into a stream bed that was dry most of the year, so that it percolated into the ground, adding to the groundwater resource. When the Los Angeles County Sanitation District was extended to Pasadena, it became more economical for Pasadena to discharge its wastewater into the county system, and the treatment plant was abandoned. Pasadena wastewater thereafter was discharged to the ocean rather than into the ground. Now the county is engaged in projects that are devoted after 30 years to reclaiming by infiltration wastewater that would otherwise be lost to sea.

521 M LAND IRRIGATION WITH MUNICIPAL EFFLUENT-AGRONOMIC ASPECTS
Overman, A. R.
Presented at 45th Annual Conf. Water Pollut. Contr. Fed., Atlanta, Ga., October 8-13, 1972.

Descriptors: Rates of application, Soil types, Nutrient removal, Florida.

Crop fertility studies have shown that increasing levels of major nutrients produce an exponential increase in yield. Crop response to municipal *effluent has also shown this characteristic. As the application rate increases, efficiency of nutrient uptake by plants decreases. The rate at which 100 percent uptake occurs depends upon the crop and soil type. In the Southeastern United States it is possible to grow crops year-round with wastewater.*

522 M THE RENOVATION OF MUNICIPAL WASTEWATER THROUGH SPRINKLER IRRIGATION (TALLAHASSEE, FLORIDA)

Overman, A. R., and T. P. Smith
Presented at 45th Annual Conf. Water Pollut. Contr. Fed., Atlanta, Ga., October 8-13, 1972.

Descriptors: Florida, Sprinkler irrigation, Rates of application, Forage crops, Odor.

Secondary effluent from a 2.5 mgd high rate trickling filter plant was applied to two forage crops on Lakeland fine sand at Tallahassee, Florida. The sand is underlain by limestone at approximately 45 feet, with the water table at 35-45 feet. Application rates of 1, 2, 4, and 8 inches per week were applied to plots 100 feet by 100 feet. Crops were sorghum-sudangrass and kenat.

Both forage crops responded well to irrigation with effluent. Yields exhibited an exponential response to increasing application rates. Nitrogen recovery of 100 percent occurred at 1-2 inches per week. No mineral deficiency or toxicity was apparent. There did not appear to be any odor problems with the sprinkler system.

523 M SPRAY IRRIGATION MANUAL

Pennsylvania Department of Environmental Resources
Bur. of Water Quality Management, Publ. No. 31, 1972.

Descriptors: Rates of application, Sprinkler irrigation, Design data, Pennsylvania, Water management (applied).

This manual incorporates factors such as soil, geology, hydrology, weather, and agricultural practice in considerations for site selection. All fields should be mowed and the crop residue removed at least once a year. Application rates in excess of 0.25 in./hr and 2 in./wk for each section of the field will be considered only under extremely extenuating circumstances supported by detailed substantiating data. Guidelines are also given for pretreatment, storage, controls, piping, sprinkler types and spacing, and distribution diameter.

524 I DISPOSAL OF INSULATION BOARD MILL EFFLUENT BY LAND IRRIGATION
Phillip, A. H.
J. Water Pollut. Contr. Fed., 43:1749-1754, August 1971.

Descriptors: Michigan, Winter storage, Soil types, Pulp and paper wastes, Spray disposal.

A system for disposal of effluent from insulation board mill has been in use on the upper peninsula of Michigan for 3 years. The effluent is stored in holding tanks from late October through April. The spray field is 100 acres in size, has Vilas sand with a rapid permeability, and has an underdrainage system to keep the water table below 5 feet. Lateral lines to the spray heads have valves activated by nitrogen gas. The system handles 500,000 gpd with a total operating cost of $20,000/yr and a total capital cost of $440,000.

525 M WASTEWATER TREATMENT AND REUSE BY LAND APPLICATION, VOLUME I--SUMMARY
Pound, Charles E., and Ronald W. Crites
U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA-660/2-73-006a, August 1973. 80 p.

Descriptors: Costs, Design data, United States, Reviews.

A nationwide study was conducted of the current knowledge and techniques of land application of municipal treatment plant effluents and industrial wastewaters. Selected sites were visited and extensive literature reviews were made. Information and data were gathered on the many factors involved in system design and operation for the three major land application approaches: irrigation, overland flow, and infiltration-percolation. In addition, evaluations were made of environmental effects, public health considerations, and costs--areas in which limited data are available. Irrigation is the most reliable land application technique with respect to long term use and removal of pollutants from the wastewater. It is sufficiently developed so that general design and operational guidelines can be prepared from current technology. Overland flow was found to be an effective technique for industrial wastewater treatment. Further development is required to utilize its considerable potential for municipal wastewater treatment. Infiltration-percolation is also a feasible method of land application. Criteria for site selection, groundwater control, and management techniques for high rate systems need further development. This volume contains a perspective and concise summary of the results of the study.

526 M WASTEWATER TREATMENT AND REUSE BY LAND APPLICATION--VOLUME II

Pound, Charles E., and Ronald W. Crites

U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA-660/2-73-006b, August 1973. 249 p.

Descriptors: Costs, Design data, United States, Reviews.

A nationwide study was conducted of the current knowledge and techniques of land application of municipal treatment plant effluents and industrial wastewaters. Selected sites were visited and extensive literature reviews were made. This volume contains the detailed information and data gathered on the many factors involved in system design and operation for the three major land application approaches: irrigation, overland flow, and infiltration-percolation. In addition, evaluations were made of environmental effects, public health considerations, and costs--areas in which limited data are available. Appendices in this volume of the two volume project report include case histories for 21 municipal and industrial sites, as well as a review of the reasons for apparent abandonment of crop irrigation at 24 cities between 1934 and 1973.

527 M WASTEWATER MANAGEMENT BY DISPOSAL ON THE LAND

Reed, S. C.

U.S. Army Corps of Eng., Cold Regions Res. Eng. Lab., Special Report 171, 1972. 183 p.

Descriptors: Spray disposal, Overland flow, Water quality standards, Wastewater treatment.

Comprehensive technical assessment of the effects and effectiveness of the methods used for disposal of wastewaters on the land. Three basic application techniques are considered: spray irrigation (SI), overland runoff (OR), and rapid infiltration (RI), and the related ecosystem responses to each. The report concludes that the product water from such operations can and should approach drinking water-irrigation water standards in quality. Of the three modes, SI offers the highest degree of reliability and potential longevity. Further definition is required for system capacity for the other two modes, but OR is given preference over RI, based on currently available information. The report not only provides an assessment of the current state of the art but documents the need for work leading to optimum criteria for design, construction and operation of cost-effective and environmentally compatible systems.

528 I PRODUCTION AND DISPOSAL PRACTICES FOR LIQUID WASTES FROM CANNERY AND FREEZING FRUITS AND VEGETABLES
Rose, W. W., et al.
In: Proc. 2nd Nat. Symp. Food Process. Wastes, U.S. Environmental Protection Agency, Washington, D.C., Report No. 12060---, March 1971. p. 109-127.

Descriptors: Design data, Suspended solids, Economic feasibility, United States, Operation and maintenance.

An overview of production and disposal practices is presented. Cost figures were estimated for an "average" plant processing fruits or vegetables. The "average" plant produces 15,000 tons of raw products in a 100 day season and has a wastewater flow of 450,000 gpd based on 3,000 gal. per ton. BOD and suspended solids would be 1,000 mg/l and 400 mg/l, respectively. The cost of irrigation would be $24,000 for construction and $4,500 for operation and maintenance. Typical costs for construction would then be about $50,000 per mgd and O&M costs would be 10¢ per 1,000 gal.

529 S DENVER SEWAGE SLUDGE RECYCLED ON THE LAND
Sabey, B. R., J. Danford, and H. H. Champlin
Compost Sci., 14(1): 4-6, January-February, 1973.

Descriptors: Subsurface irrigation, Economic feasibility, Colorado.

While the research to date indicates that numerous problems are associated with recycling of sewage sludge in soils, the results also indicate that the possibility of overcoming the problems is good. Much more research is required to determine the feasibility and practical use of this method of disposal. Colorado State University Experiment Station is intensifying its research efforts on the problem.

530 S IRRIGATING WITH LIQUID DIGESTED SLUDGE
Seabrook, B. L.
Compost Sci., 14(1): 26-27, January-February 1973.

Descriptors: Heavy metals, Activated sludge effluents, Odor, Public acceptance, Hertfordshire, England.

In contrast to the problems created by the dumping of sanitary wastes into rivers, lakes and oceans including the metals in such wastewater, the metals problem involved in sewage irrigation on land is by far the lesser problem. The technique of treating the secondary plant effluent *so that 97% of it can be discharged directly into surface waters so that the balance can be irrigated in the form of liquid digested sludge has now been adopted by approximately 40% of all municipal treatment works in England. Only the remaining 3% consists of effluent plus digested sludge, free of objectionable odors, and brings no associated fly problem with it, it comes closer than any other irrigation technique to meeting the aesthetic requirements of the community in which it would be used. The Hertfordshire experience over the last two decades has demonstrated that it is acceptable and practical for certain communities of 500,000 population.*

531 I WASTE TREATMENT IN CHINA: ANCIENT TRADITIONS AND HIGH TECHNOLOGY

Sebastian, F. P., Jr.
AMBIO (Oslo, Norway), 1(6): 209-216, November/December 1972.

Descriptors: Costs, Wastewater treatment, China.

An American executive of a firm specializing in environmental technology visited China and reports that while old traditions are followed in the primitive recycling of human wastes ("night soil"), high technology is applied in industrial waste treatment.

532 M THE USE OF SEWAGE FOR IRRIGATION--A LITERATURE REVIEW

Sepp, E.
Bur. Sanit. Eng., Calif. State Dept. Pub. Health, 1971.

Descriptors: Pathogenic bacteria, Reviews, Public health regulations, United States, Europe.

After reviewing literature from many areas in the U.S., Europe, and the Mid-East, it was concluded that the consumption of raw vegetables irrigated with sewage has given rise to outbreaks of typhoid fever and worm infection. Crops grown in fields may be contaminated directly by sewage and polluted water, or indirectly through contact with polluted soil. Pathogenic bacteria, amoeba cysts, and helminth eggs cannot penetrate the surfaces of healthy, unbroken vegetables. Survival times of the various organisms are reported. Studies indicate that the coliform bacteria count on grass and clover leaves drops to the natural level 14 days after sewage application. Bacteriological standards for irrigating crops with sewage have been established in some of the western states of the U.S. and in Europe. Wide variation in the requirements, however, exists.

533 M DISPOSAL OF DOMESTIC WASTEWATER BY HILLSIDE SPRAYS
Sepp, E.
Amer. Soc. Civil Eng., J. Environ. Eng. Div., 99(332): 109-121, 1973.

Descriptors: Wastewater disposal, Public health regulations, Soil physical properties, Spreading basins, California.

The state and local health departments have long supported the land disposal principle for mountain areas, and the practicality of this approach has been substantiated through the years. In 1967, the State Board of Public Health adopted a formal policy for the protection of mountain waters. The goal of the policy was no direct discharge; this could be alternatively achieved by either land confinement, export of wastewater, or water reclamation. Subsequent studies (20) have demonstrated that land disposal systems are much more reliable than systems which discharge effluent directly into mountain waters, and that containment of wastes on land is achievable even under the most adverse conditions. Hillside spraying is a reliable method of land disposal of domestic wastewater which can be used in areas where the soils are not suitable for subsurface disposal or the terrain is too rough for the construction of evaporation-percolation ponds.

534 M SELECTED IRRIGATION RETURN FLOW QUALITY ABSTRACTS 1968-1969
Skogerboe, G. V., et al.
U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA/R2-72-094, November 1972. 211 p.

Descriptors: Bibliographies, Water quality data, Reviews.

This first annual issue has been compiled from approximately 100 sources of material which have been searched for articles pertinent to the National Irrigation Return Flow Research and Development Program. It contains more than 400 abstracts, which are placed in sections according to the category and subgroup classifications used by the Water Resources Scientific Information Center. The abstracts cover research that is being conducted at numerous institutions throughout the Western United States as well as other portions of the world. Each abstract contains descriptors and identifiers as well as full bibliographical information. There are also indexes by author and subject.

The range of subjects covered is vast. For example: "Characteristics and Pollution Problems of Irrigation Return Flow," prepared by the Utah State University Foundation contains a bibliography with references to articles and reports published prior to 1968, which are pertinent to irrigation return flow quality control. A quite different example is: "2,4-D Diffusion in Saturated Soils; A Mathematical Theory."

535 M *DISPOSAL OF MUNICIPAL WASTE WATER THROUGH FOREST IRRIGATION*
Sopper, William
Environ. Pollut., 1: 263-284, 1971.

Descriptors: Rates of application, Silviculture, Groundwater recharge, Wastewater disposal, Water reuse, Penn State, Pennsylvania.

Serious pollution problems are often created by the disposal of municipal waste water into surface waters. Research results indicate that, with properly programmed application rates, large volumes of waste water can be satisfactorily renovated through irrigation of forestland, and considerable amounts of high-quality water recharged to the groundwater reservoir. In addition, secondary benefits such as increased tree growth, increased site productivity, and site amelioration have also been obtained. The deliberate reclamation of waste water for potential reuse is one of the keys to optimum utilization of our water resources.

536 M *EFFECTS OF TREES AND FORESTS IN NEUTRALIZING WASTE*
Sopper, William E.
Institute for Research on Land and Water Resources, 1971. 16 p.

Descriptors: Economic feasibility, Forage crops, Silviculture, Soil physical properties, Penn State, Pennsylvania.

Research has indicated that the living-filter system for renovation and conservation of municipal wastewater is feasible and that combinations of agronomic and forested areas provide the greatest feasibility in operation. This system is feasible whenever the following site conditions exist: (1) Soil with a sufficient infiltration and percolation capacity; (2) Soil with sufficient chemical-adsorptive capacity, water-retentive capacity, and depth to the groundwater table; (3) Low relief with a vegetative cover and a protective accumulation of surface organic matter; and, (4) A groundwater aquifer with a fairly deep water table.

537 M *RECYCLING TREATED MUNICIPAL WASTEWATER AND SLUDGE THROUGH FOREST AND CROPLAND*
Sopper, W. E., and L. T. Kardos (ed.)
Univ. Park, Penn State Univ. Press, 1973. 479 p.

Descriptors: Reviews, Wastewater treatment, Pennsylvania, Silviculture.

Abstracts of 33 papers delivered at the symposium. Current knowledge related to the potential of using land areas for the disposal of treated municipal wastewater and sludge is reviewed and discussed. There is an attempt to determine technological gaps and research needs.

538 M EFFECTS OF IRRIGATION OF MUNICIPAL SEWAGE EFFLUENT ON SPOIL BANKS

Sopper, William E., and L. T. Kardos
Univ. Park, Penn State Univ., Institute for Research on Land & Water Resources, Completion Report, December 1971. 11 p.

Descriptors: Forage crops, Silviculture, Penn State, Pennsylvania, Plant diseases, Land reclamation.

Approximately 25 tons of spoil material were placed in each of ten large boxes, 32 feet long, 4 feet wide, and 4 feet deep. In April, 1969, each box was planted with seven species of tree seedlings--Japanese larch, white spruce, Norway spruce, white pine, European alder, hybrid poplar, and black locust. In addition, orchard grass and tall fescue grasses and crownvetch and birdsfoot trefoil legumes were broadcast seeded in each box. Two boxes were untreated as controls. The remaining eight boxes were divided into four groups of two for treatment. The four weekly treatments applied were: (1) 2 inches of sewage effluent, (2) 1 inch of sewage effluent and 1 inch of sludge, (3) 2 inches of sewage effluent and 2 inches of sludge, and (4) 2 inches of sludge. Treatments were applied for 24 weeks from May to October in 1969 and 1970. There was 100 percent mortality in the control boxes. Tree seedling survival and growth on all treated boxes was excellent. Highest tree seedling survival was obtained with the 2 inches of sewage effluent treatment. Survival percentages were 65% for black locust, 40% for white pine, 38% for European alder, 35% for Norway spruce, 10% for hybrid poplar, and 3% for Japanese larch. Treatments were very effective in establishing a groundcover of grasses and legumes particularly in those that included sludge applications. Percolate samples collected also indicated that considerable amounts of dissolved minerals were removed by the spoil material and the quality of the percolating water was greatly improved.

539 M VEGETATION RESPONSES TO IRRIGATION WITH MUNICIPAL WASTEWATER

Sopper, W. E., and L. T. Kardos
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 271-294.

Descriptors: Rates of application, Sprinkler irrigation, Penn State, Pennsylvania.

Spray irrigation of treated municipal wastewater on cropland and in forest stands over a 10-year period (1963-1972) significantly affected vegetation growth. Weekly applications of one and two inches of sewage effluent increased diameter growth of mixed hardwood species. Irrigation of red pine with one inch of sewage effluent per week resulted in slight increases in annual diameter and height growth; whereas application of two inches per week reduced both diameter and height growth. White spruce showed the greatest growth response. Applications of effluent at two inches per week greatly increased diameter growth and tripled the total height of young saplings during the ten year period. Significant changes were also found in species composition and growth of herbaceous vegetation in the forested areas. The effects of effluent irrigation in forested areas on tree mortality and winter ice breakage are also discussed.

540 S PROTECTION OF PUBLIC HEALTH
Sorber, C. A.
In: Proc. Conf. Land Disposal of Municipal Effluents and Sludges, U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA-902/9-73-001, March 1973. p. 201-209.

Descriptors: Groundwater contamination, Pathogenic bacteria, Vegetation damage, Aerosols.

Public health considerations in land application include aerosol travel and infectivity, bacterial contamination of vegetables, and groundwater pollution from toxic chemicals and pathogens. A discussion is included of each of these topics plus current research in the field.

541 M PROBLEM DEFINITION STUDY: EVALUATION OF HEALTH AND HYGIENE ASPECTS OF LAND DISPOSAL OF WASTEWATER AT MILITARY INSTALLATIONS
Sorber, C. A., S. A. Schaub, and K. J. Guter
U.S. Army Medical Environ. Eng. Res. Unit, Aberdeen Proving Ground, Md., August 1972. 32 p.

Descriptors: Viruses, Groundwater contamination, Aerosols, Bibliographies.

Many of the detrimental health and hygiene aspects of land application would be significantly reduced by proper wastewater pretreatment (secondary treatment, filtration, complete disinfection). By choosing *a land disposal site that has from 5 to 10 feet of continuous fine soil, biological contamination of groundwater should be avoided. The probability of inhaling pathogenic aerosols near a spray irrigation site is significant. Chemical components of sewage may enhance the viability of bacteria, virus and protozoans in aerosols. Pathogenic microorganisms may survive longer in sewage aerosols and in soil than common indicator organisms such as coliform organisms. Mosquito breeding is enhanced as a result of ponding in land disposal areas. In areas where land application is the first step in a water recycle program, total dissolved solids (sodium and nitrate ion buildup) in the groundwater supply can be a problem.*

542 M TERTIARY WASTEWATER TREATMENT MADE PRACTICAL
Sprowl, T. M., and R. M. Hopkins
Amer. City, 87: 65-69, April 1972.

Descriptors: Florida, Spray disposal, Suspended solids, Tertiary treatment, Recreational facilities.

The City of Cocoa Beach, Florida, uses spray irrigation for effluent disposal. The capacity of the activated sludge plant is 3 mgd. The original 1.5 mgd trickling filter plant was expanded and converted to contact stabilization. The effluent is chlorinated and used for irrigation. The soil is primarily a shell composition since the entire area complex was dredged from the Banana River by hydraulic filling. BOD reduction in the plant is from 100 mg/l to less than 1 mg/l and suspended solids reduction is from 100 mg/l to 3 mg/l. The wastewater treatment processes are described in detail.

543 S MODEL OF ORGANIC WASTES RECYCLING
Stickelberger, D.
IRCWD News, 3: 2-6, March 1972.

Descriptors: Recycling nutrients, Sludge disposal.

Excerpt from a speech proposing a thermodynamic model for organic waste recycling. Waste material cannot be destroyed or even removed. The refuse which has seemingly been disposed of always reappears in one form or another, either in the air, water, soil or all three "elements" at once. The author maintains that "the disrupted ecological system must be brought into balance and aligned with initial production conditions through buffered feedback loops of end products." He suggests that his model will be specially useful in developing countries.

544 M GREEN LAND--CLEAN STREAMS: THE BENEFICIAL USE OF WASTE WATER THROUGH LAND TREATMENT
Stevens, R. M.
Center for the Study of Federalism, Temple Univ., Philadelphia, Pa., 1972.

Descriptors: Overland flow, Pennsylvania, Public health regulations, Surveys, Costs.

The report describes over forty different facilities on the basis of existing literature, questionnaires, and interviews. Sites described are classified as infiltration or overland flow and as being used for disposal or reutilization. Data include costs, pollutant removal rates, and area to volume relationships. Also discussed are the social and political aspects of land treatment including an appendix of individual state standards.

545 M SURVEY OF FACILITIES USING LAND APPLICATION OF WASTEWATER
Sullivan, Richard H., et al.
U.S. Environmental Protection Agency, Washington, D.C., Report No. EPA-430/9-73-006, July 1973. 377 p.

Descriptors: United States, Surveys, Wastewater disposal, Reviews.

The American Public Works Association in 1972, conducted a field survey of 100 facilities where land application of domestic or industrial wastewater effluents were applied to the land, as contrasted to the conventional method of discharging such effluents to receiving waters. In addition, an extensive bibliography was compiled (to be published separately); data were gathered from many other existing land application facilities across the country; determinations were made as to State regulations governing the use of land application facilities; and a survey was made of experience gained in many foreign countries. The facilities surveyed were relatively large, with long-established operations in order that as may viable operating experiences as possible could be obtained. The surveyed land application facilities utilizing domestic wastewaters were predominantly located in the western and southwestern portions of the nation, while industrial facilities were generally sited in the northeastern section, because this is where the majority of such installations are in service. Agricultural wastes facilities and evaporation-percolation or spray runoff type facilities were outside the scope of the investigation. Ninety-nine tables and the collected data are presented. Photographs of representative facilities are used to illustrate land application practices.

546 S PROCESS CONTROL AT SHEFFIELD'S SLUDGE FILTRATION PLANT

Swanick, K. H.
Filtr. Separ., 8: 137-139, March/April 1971.

Descriptors: Aerobic digestion, Sludge disposal, Dewatering, Design data, England.

The sewage sludge filter pressing plant at Sheffield's Blackburn Meadows Sewage Works is one of the largest installations of its kind in the world. The plant consists essentially of sludge storage tanks, milk of lime tanks, variable rate sludge and lime pumps, flash mixers conditioned sludge storage tanks and six air compressors with associated pairs of rams, which feed the 36 filter presses.

547 S UTILIZATION OF MUNICIPAL SOLID WASTE COMPOST: RESEARCH RESULTS AT MUSCLE SHOALS, ALABAMA

Terman, G. L., and D. A. Mays
Compost Sci., 14(1): 18-21, January-February 1973.

Descriptors: Costs, Forage crops, Vegetable crops, Alabama.

Experiments conducted show that large tonnages of municipal compost can be applied on grassland or cropland and result in positive yield responses. Economic comparisons are then made between the actual value of dry compost in terms of crop response and the estimated costs of $8 to $30 per ton of garbage (double these costs per ton of compost) for producing compost from municipal wastes. Carlson and Menzies concluded that benefits to agriculture from applying waste to land are generally minimal, but the benefits to urban governments are substantial. Thus, composting of organic wastes should be considered largely as a useful alternative method of disposal.

548 M THE SOIL AS A PHYSICAL FILTER

Thomas, R. E.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 38-45.

Descriptors: Anaerobic conditions, Soil physical properties, Clogging (soil).

Septic tank-soil absorption systems are the most widely used of the approaches devised by man for wastewater disposal to the soil, and *there are about 15 million homes in the United States utilizing this approach. Water movement through the soil is essential to successful use of septic tank systems, and much of the research effort has been directed to studies on soil clogging. The research efforts directed to identifying the causes of soil clogging elucidated three important factors to consider in selecting management practices for applying wastewater to the land. These three factors are (1) the zone of clogging which reduces the water intake rate is at or near the soil surface, (2) the most severe clogging develops in an anaerobic environment, and (3) the severe clogging developed under anaerobic conditions can be removed by drying this clogged surface layer of soil.*

549 M LAND DISPOSAL II--AN OVERVIEW OF TREATMENT METHODS
Thomas, R. E.
J. Water Pollut. Contr. Fed., 45: 1476-1484, July 1973.

Descriptors: Overland flow, Wastewater treatment, Reviews, Wastewater disposal.

The application of wastewater to the land for disposal, treatment and/or reuse is discussed in a general overview of the subject. The discussion covers historical developments leading to the current wave of national interest and some methods which show promise for continuing use. Historical aspects covered include the number of land application systems in use, the purposes of these systems and experiences stemming from long-term operation of some systems. The discussion of methods which show promise for continuing use include crop irrigation systems, infiltration-percolation systems, and overland flow systems. Information presented shows the general capability of each method for treatment and/or reuse of a wastewater. Topics covered include the technical aspects of the health risk to humans, the effects on crop production, the effects on soil properties, the effects on groundwater quality, and the expected treatment efficiency.

550 M EXPERIENCES WITH LAND SPREADING OF MUNICIPAL EFFLUENTS
Thomas, R. E., and C. C. Harlin, Jr.
In: Proc. 1st Annual Workshop Land Renovation of Waste Water in Florida, Tampa, June 1972. p. 151-164.

Descriptors: Overland flow, Rates of application, Soil physical properties, Groundwater recharge.

There are three categories of land application: (1) infiltration-percolation, (2) cropland irrigation, and (3) spray-runoff. Infiltration-percolation for groundwater recharge can be used on coarse textured soils with loadings up to 400 ft per year under ideal conditions. Crop irrigation by spraying or spreading requires more land as loadings are 1 to 2 inches per week with total growing season applications of less than 8 ft per year. Spray-runoff is especially suited to use with impermeable soils as treatment is on the surface and more than half the applied effluent is returned directly to surface waters as planned and controlled runoff.

Research studies on infiltration-percolation include Whittier Narrows, Santee, Phoenix, Hemet, California, and Detroit Lakes, Minnesota. Crop irrigation research is being conducted at Penn State, Muskegon, Michigan, and Belding, Michigan. The spray-runoff approach has not been used for municipal wastewater but in-house research is being conducted at Ada, Oklahoma.

551 M REMOVAL OF PHOSPHORUS AND NITROGEN FROM WASTEWATER EFFLUENTS BY INDUCED SOIL PERCOLATION
Tilstra, J., et al.
J. Water Pollut. Contr. Fed., 44: 796-805, May 1972.

Descriptors: Phosphorus removal, Nutrient removal, Nitrification, Denitrification, Minnesota.

This study was conducted to determine the nutrient removal characteristics of 20 acres of city-owned peat soil immediately down-gradient from the Detroit Lakes, Minnesota, municipal wastewater outfall. Phosphorus removal varied from 76 to 92 percent at a loading of 0.75 gpd/sq ft. Nitrogen content in the soil was so high that nitrification and leaching of nitrates offset any nitrogen removal processes.

552 M PHOSPHORUS AND NITRATE LEVELS IN GROUNDWATER AS RELATED TO IRRIGATION OF JACK PINE WITH SEWAGE EFFLUENT
Urie, D. H.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 176-183.

Descriptors: Sprinkler irrigation, Rates of application, Soil types, Phosphorus removal.

Secondary sewage effluent was applied by sprinkler irrigation to a 35-year-old jack pine (Pinus banksiana L) plantation on Kalkaska loamy sand. Irrigation at the rate of 2.5 inches per week resulted in increases in nitrate-N levels of groundwater at 3 m depths at the end of the first growing season. In 44 weeks of operation, 61 inches, 141 lb/acre phosphorus, and 170 lb/acre nitrogen were applied. Phosphorus concentrations in groundwater were unchanged. Diameter growth of dominant trees was increased.

553 S PALZO RECLAMATION PROJECT, VIENNA RANGER DISTRICT, SHAWNEE NATIONAL FOREST, WILLIAMSON COUNTY, ILLINOIS: Final Environmental Statement
U.S. Department of Agriculture
Forest Service, 1972. 102 p.

Descriptors: Anaerobic digestion, Land reclamation, Illinois, Heavy metals, Nitrate contamination.

The pilot project described in this statement deals with the application of anaerobically digested municipal waste on strip-mined land. The expected environmental impact will be to significantly reduce the water pollution problem now associated with the tract as well as to control extensive erosion through establishment of vegetative cover. The long-range environmental impact could be the development of techniques for reclaiming thousands of acres of strip-mined land, resulting in the general improvement of water quality in areas similar to Southern Illinois. This land may be the ideal place for the deposition of large volumes of waste which are presently a growing problem in large metropolitan areas. Adverse environmental effects which cannot be avoided may include slight increases in concentrations of cadmium, chromium, nickel, and nitrates in the runoff.

554 M WASTEWATER MANAGEMENT BY DISPOSAL ON THE LAND
U.S. Army Corps of Engineers
Cold Regions Res. Eng. Lab., Hanover, N.H., Special Report 171, May 1972. 183 p.

Descriptors: Reviews, Spray disposal, New Hampshire, Overland flow, Operation and maintenance.

This state-of-the-art review considers three land disposal techniques: spray irrigation (SI), overland runoff (OR), and rapid infiltration (RI).

Each is considered in detail including such aspects as wastewater characteristics, water quality goals, site conditions, operational criteria, and ecosystem response.

The concept of renovative capacity is introduced which assumes that there is a finite depth of soil in which major renovation occurs. For the following site the assumed active depths are given: Penn State, SI: 6 inches; Paris, Texas, OR: 2 inches; Flushing Meadows, Arizona, RI: 3 feet. The liquid volume applied to each site, in terms of inches per week is then divided by the renovative capacity, and the ratio, tentatively called the capacity index, is the result. The ratio may be in terms of gallons per cubic ft or it may be dimensionless. For the three sites mentioned above the dimensionless ratios are: Penn State 0.325; Paris, Texas 1.47; and Flushing Meadows 4.68. The liquid volume used was: Penn State 2 in./wk; Paris, Texas 3 in./wk; and Flushing Meadows 14 ft/wk.

555 M THE USE OF LAND AS A METHOD OF TREATING WASTEWATER

U.S. Army Corps of Engineers
Chicago-South End of Lake Michigan Area Wastewater Management Study, December 1972.

Descriptors: Chicago, Illinois, Economic feasibility, Operation and maintenance, Planning, Wastewater disposal.

This is a report on the study of the disposal of wastewater from the Chicago area. The report analyzes the use of land as a disposal medium. Three sections compose the body of the report: land treatment concept, operational and management considerations, and land treatment evaluation. Each section is covered comprehensively. Two other methods of treatment will be covered in other reports.

556 M A PILOT WASTEWATER MANAGEMENT PROGRAM FOR CHICAGO, CLEVELAND, DETROIT, SAN FRANCISCO, AND THE MERRIMACK BASIN

U.S. Army Corps of Engineers
Office of Chief of Engineers, 1971. 84 p.

Descriptors: Economic feasibility, Planning, Water management (applied), Costs, United States.

The purpose of this feasibility study being undertaken within the planning authority of the Corps of Engineers for a study of water supply for the

Northeastern United States is to investigate and evaluate all appropriate alternatives for total wastewater management for the Merrimack River Basin, and to serve as the basis for the development of detailed plans in subsequent studies. The feasibility study will be completed 15 July, 1971.

557 M ALTERNATIVES FOR MANAGING WASTEWATER, FOR SOUTHEASTERN MICHIGAN
U.S. Army Corps of Engineers
Detroit District, Summary Report, 1971.

Descriptors: Planning, Michigan, Public acceptance, Economic feasibility, Wastewater treatment.

The objective of this feasibility study is to identify the present and future water pollution problems of the study area and to evaluate the feasibility and consequences of alternative wastewater management programs. The study considers the economic, social, institutional and environmental impacts of the alternatives, in addition to the technical aspects. The alternatives are: (1) water disposal; (2) land disposal; and (3) combination disposal. Advantages, disadvantages and costs of each are considered.

558 M ALTERNATIVES FOR MANAGING WASTEWATER, FOR CLEVELAND-AKRON METROPOLITAN AND THREE RIVERS WATERSHED AREAS
U.S. Army Corps of Engineers
Buffalo District, Summary Report, 1971. 64 p.

Descriptors: Ohio, Planning, Public acceptance, Economic feasibility, Wastewater treatment.

Preliminary alternatives were developed which were technically feasible. The impacts of three of those alternatives on environmental quality, social well-being and national and regional economic development were evaluated. They are: (1) water disposal; (2) land disposal; and (3) combination land-water disposal. Each of the alternatives would provide the region with a program that would virtually eliminate pollution in surface waters and reduce pollutant inflows to Lake Erie. Each exhibits distinct characteristics and problems, although most of the problems can be solved by modifications.

559 M ALTERNATIVES FOR MANAGING WASTEWATER IN THE SAN FRANCISCO BAY AND SACRAMENTO-SAN JOAQUIN DELTA AREAS

U.S. Army Corps of Engineers
San Francisco District, Summary Report, 1971. 63 p.

Descriptors: California, Planning, Water management (applied), Wastewater treatment.

Three basic regional strategies, or a combination of two, could meet the future wastewater management requirements of the Bay Delta area. These are ocean disposal, estuarine disposal, land disposal and a combination of the last two. Each alternative evaluated requires a high degree of purification of wastewaters in order to give assurance of environmental protection. The resulting treated wastewaters could, therefore, be of adequate quality for a variety of reuses.

560 M A REVIEW OF SPRAY IRRIGATION PRACTICE--PROS AND CONS

Van Eyck, M.
Presented at 1971 Meet. Mich. Water Pollut. Contr. Ass., 1971.

Descriptors: Sprinkler irrigation, Soil physical properties, Flood irrigation, Michigan, Reviews.

Some 30 factors that need to be considered for successful spray irrigation are presented. The more important factors include (1) pretreatment to secondary quality, (2) land availability, (3) permeable, loamy soil with a low groundwater table, (4) storage for winter flows, (5) flexible, semi-automatic operation to reduce manual attention, (6) mineral characteristics of the wastewater, and (7) economic feasibility with respect to tertiary treatment processes. In 1887, broad (flood) irrigation was begun at Calumet, Michigan, in the Upper Peninsula and is still being operated on a daily rotation of seven application areas.

There are probably over 30 other sewage spray systems in Michigan that are planned or recently completed. Imhoff and Fair state that sewage irrigation is usually not practiced in areas having more than 25 inches per year of rainfall, which makes Michigan (30 in. per year) a marginal state for this method.

561 S UTILIZATION OF MUNICIPAL ORGANIC WASTES AS AGRICULTURAL FERTILIZERS

Vlamis, J., and D. E. Williams
Compost Sci., 13(1): 26-28, January-February 1972.

Descriptors: Recycling nutrients.

Sewage sludge and garbage compost found to be good sources of plant nutrients.

562 M REMOVAL OF METAL IONS BY SOIL
Wentink, G. R., and J. E. Etzel
J. Water Pollut. Contr. Fed., 44: 1561-1574, August 1972.

Descriptors: Rates of application, Soil types, Heavy metals.

Three types of soil were used in the study: Xenia silt loam, Chalmers silty clay loam, and Elston loam. Each soil was treated with copper, chrome and zinc ion solutions. The results show that complete removal of chrome was possible up to concentration of 300 mg/l with any type of soil. Removal of copper was complete after an initial conditioning period for any type of soil. Removal of zinc at application rates as high as 300 mg/l can be accomplished with an efficiency of no less than 99.7 percent.

563 I WASTEWATER FROM THE AGRICULTURAL AND FOOD INDUSTRIES
Vermes, L.
Presented at 12th Int. Symp. (Appendix 6), Budapest, March 1970. 1972, 4 p.

Descriptors: Food processing wastes, Salinity, Vegetable crops, Forage crops.

Author deals primarily with research on the canning and sugar-manufacturing industries. The effluent from canneries is rich in carbohydrates, proteins and mineral salts. The irrigation of alfalfa, fodder beet and sugar beet crops boosts yields two to two and a half times. For irrigation purposes, however, the salt content of the water initially used by the cannery must be limited. Storage of the wastewater for a three-week period does not endanger its fitness for irrigation. Its content in organic ingredients--3,500 mg/l--is significant, as is its potassium content--155 mg/l. Tests on wastewater from sugar manufacturing reveal a mineral content of 1,000 to 3,000 mg/l. Its high content in calcium and potassium is desirable for crops. In no case does its sodium content exceed a level permissible in irrigation.

564 M LAGOON-IRRIGATION WASTEWATER TREATMENT SYSTEMS

Williams, T. C., Williams and Works
Presented at 7th Amer. Water Resources Conf, Washington, D.C., October 1971. 12 p.

Descriptors: Oxidation lagoons, Reviews, Michigan, Design data.

Williams and Works has designed over 40 municipal wastewater stabilization lagoons for the treatment of raw domestic wastes. Report discusses their experience with actual operations.

565 M UTILIZATION OF SPRAY IRRIGATION FOR WASTEWATER DISPOSAL IN SMALL RESIDENTIAL DEVELOPMENTS

Williams, T. C.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 385-395.

Descriptors: Winter storage, Flood irrigation, Michigan, Costs, Design data.

The author presents experience with 16 pond and irrigation wastewater treatment systems in various municipalities and residential developments in Michigan. Eleven of these are complete and the other five will be operational in 1974. Most designs include an anaerobic or a facultative pond followed by series of aerobic ponds. As a result of the climate in Michigan, the BOD loadings on ponds are limited to a maximum of 20 lb of BOD per acre. As another consequence of the climate, wastewater is not applied in the winter, and a minimum of 5 months' storage of the wastewaters is required. Design data on solid set sprinklers, traveling center-pivot sprinklers, and flood irrigation are included. Capital costs are given on a per capita basis for various ranges of design population and operation and maintenance costs are also included.

566 I CANNERY WASTE DISPOSAL AT ITS BEST

Wyndham, Robert
Compost Sci., 12(4): 30, July-August, 1971.

Descriptors: California, Food processing wastes, Fruit crops, Rates of application.

Various types of fruit wastes from canneries near Gilroy, California, were spread over farmland and plowed into the soil at rates up to 480 tons per acre. Plant growth was slightly depressed on land used with high rates of fruit waste disposal, but it is felt that this is a temporary condition due to acids from the wastes.

567 M WASTEWATER RECLAMATION BY IRRIGATION

Young, Reginald H. F., Paul C. Ekern, and L. Stephen Lau
J. Water Pollut. Contr. Fed., 44: 1808-1814, September 1972.

Descriptors: Hawaii, Planning, Design data, Dissolved solids, Viruses.

This study, planned in central Oahu, will develop data pertinent to Hawaii regarding transmission of viruses and passage of dissolved materials under controlled field conditions in which wastewater effluent is applied to irrigate grass sod and sugar cane. When coupled with controlled laboratory data and existing general knowledge, the information should offer a sound base for determining the expected degree of health hazard and mineral buildup in the receiving groundwater for various combinations of operating conditions of a wastewater reclamation system by irrigation in Hawaii. Alternatives for the management of regional water resources--water supply and wastewater disposal--for Oahu are dependent on the knowledge to be developed. Such knowledge may be applicable to other similar locations in the Hawaiian Islands. The study will aid in understanding the viability and retention of wastewater-borne viruses in a tropical soil-water-plant environment.

568 M ECOLOGICAL AND PHYSIOLOGICAL IMPLICATIONS OF GREENBELT IRRIGATION WITH RECLAIMED WATER

Younger, V. B., et al.
In: Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Sopper, W. E., and L. T. Kardos (ed.), Univ. Park, Penn State Univ. Press, 1973. p. 396-407.

Descriptors: California, Greenbelts, Rates of application, Deep percolation, Forage crops.

In 1970 a research project attacking the sewage disposal and fire protection problems in Southern California mountains was constructed in the San Bernardino National Forest by the University of California in cooperation with the California Division of Forestry and the U.S. Forest Service. Its primary objective was to study the feasibility of using wastewater from mountain communities to irrigate greenbelts of native and introduced plant materials. The study site of 25 acres consists of

48 experimental plots with four automatically controlled sewage effluent irrigation treatments (0, 1, 2, 4 inches per week). Part of the plots were cleared of all brush and others left uncleared. Subplots of various conifers, grasses, shrubs and groundcovers were planted in some plots cleared of the native chaparral.

Results into the second year of irrigation show that fuel moisture levels (moisture content of chaparral stems) is increased directly with water application rate. Native grass populations have increased many fold on plots receiving 2 and 4 inches of water per week. One inch per week is insufficient to significantly change composition of the chaparral plant community or to satisfactorily establish introduced plants. Deep water percolation through chaparral vegetation appears to be achieved only at the four-inch rate.

☆U.S. GOVERNMENT PRINTING OFFICE:1974 546-319/448 1-3